TR-202
October 2002

Texas Water Resources Institute
make every drop count

Economic and Conservation Evaluation of Capital Renovation Projects: Harlingen Irrigation District Cameron County No. 1 – Canal Meters and Telemetry Equipment, Impervious-Lining of Delivery Canals, Pipelines Replacing Delivery Canals, and On-Farm Delivery-Site Meters

M. Edward Rister
Ronald D. Lacewell
Allen W. Sturdivant
John R. C. Robinson
Michael C. Popp
John R. Ellis

Texas Water Resources Institute

Texas A&M University

TR-202
October 2002

Texas Water Resources Institute
make every drop count

Economic and Conservation Evaluation of Capital Renovation Projects: Harlingen Irrigation District Cameron County No. 1 – Canal Meters and Telemetry Equipment, Impervious-Lining of Delivery Canals, Pipelines Replacing Delivery Canals, and On-Farm Delivery-Site Meters

M. Edward Rister
Ronald D. Lacewell
Allen W. Sturdivant
John R. C. Robinson
Michael C. Popp
John R. Ellis

Texas Water Resources Institute

Texas A&M University

Rio Grande Basin Initiative administered by the Texas Water Resources Institute of the Texas A&M University System with funds provided through a federal initiative, "Rio Grande Basin Initiative," administered by the Cooperative State Research, Education, and Extension Service, U.S. Department of Agriculture, under Agreement Numbers 2001-45049-01149 and 2001-34461-10405.

Preface[1]

Recognizing the seriousness of the water crisis in South Texas, the U.S. Congress enacted Public Law 106-576, entitled "The Lower Rio Grande Valley Water Resources Conservation and Improvement Act of 2000 (Act)." In that Act, the U.S. Congress authorized water conservation projects for irrigation districts relying on the Rio Grande River for supply of agricultural irrigation, and municipal and industrial water. Several phases of project planning, development, evaluation, prioritization, financing, and fund appropriation are necessary, however, before these projects may be constructed.

Based on language in the Act, the "Guidelines for Preparing and Reviewing Proposals for Water Conservation and Improvement Projects Under Public Law 016-576 (Guidelines)" require three economic measures as part of the Bureau of Reclamation's evaluation of proposed projects:

- Number of acre-feet of water saved per dollar of construction costs;
- Number of British Thermal Units (BTUs) of energy saved per dollar of construction costs; and
- Dollars of annual economic savings per dollar of initial construction costs.

South Texas irrigation districts have an extensive system of engineered networks – including 24 major pumping stations and lifts, 800 miles of large water mains and canals, 1,700 miles of pipelines, and 700 miles of laterals that deliver water to agricultural fields and urban areas. Yet, many key components are more than 100 years old, outdated and in need of repair. Texas Agricultural Experiment Station and Texas Cooperative Extension economists and engineers are collaborating with Rio Grande Basin irrigation district managers, their consulting engineers, the Bureau of Reclamation, and the Texas Water Development Board to perform economic and energy evaluations of the proposed projects.

Proposed capital improvement projects include, among others, (a) meters for monitoring in-system flows and improving management of system operations; (b) lining for open-delivery canals and pipelines to reduce leaks, improve flow rates, and increase head at diversion points; and (c) pumping plant replacement.

The economists have developed a spreadsheet model, Rio Grande Irrigation District Economics (RGIDECON©), to facilitate the analyses. The spreadsheet's calculations are attuned to economic and financial principles consistent with capital budgeting procedures — enabling a comparison of projects with different economic lives. As a result, RGIDECON© is capable of providing valuable information for prioritizing projects in the event of funding limitations. Results of the analyses can be compared with economic values of water to conduct cost-benefit analyses. Methodology is also included in the spreadsheet for appraising the economic costs

---

[1] This information is a reproduction of excerpts from a guest column developed by Ed Rister and Ron Lacewell and edited by Rachel Alexander for the first issue of the Rio Grande Basin Initiative newsletter published in *Rio Grande Basin Initiative Outcomes, 1*(1) (Rister and Lacewell).

associated with energy savings. There are energy savings both from pumping less water forthcoming from reducing leaks and from improving the efficiency of pumping plants.

The economic water and energy savings analyses provide estimates of the economic costs per acre-foot of water savings and per BTU (kwh) of energy savings associated with one to five proposed capital improvement activity(ies) (each referred to as a component). An aggregate assessment is also supplied when two or more activities (i.e., components) comprise a proposed capital improvement project for a single irrigation district. The RGIDECON© model also accommodates "what if" analyses for irrigation districts interested in evaluating additional, non-Act authorized capital improvement investments in their water-delivery infrastructure.

The data required for analyzing the proposed capital improvement projects are assimilated from several sources. Extensive interactions with irrigation district managers and engineers are being used in combination with the Rio Grande Regional Water Planning Group Region M report and other studies to identify the information required for the economic and conservation investigations.

The RGIDECON© model applications will provide the basis for Texas Water Resources Institute reports documenting economic analysis of each authorized irrigation district project. An executive summary of the economic analysis of each authorized project will be provided to the irrigation districts for inclusion in their project report. The project reports will be submitted to the Bureau of Reclamation for evaluation prior to being approved for funding appropriations from Congress.

Subsequent to the noted legislation and approval process developed by the Bureau of Reclamation for evaluating legislation-authorized projects being proposed by Rio Grande Basin Irrigation Districts, the binational North American Development Bank (NADBank) announced the availability of an $80 million Water Conservation Fund for funding irrigation projects on both sides of the U.S.-Mexico border. The NADBank also announced a merging of its board with that of the Border Environment Cooperation Commission (BECC), resulting in the latter assuming a facilitation role in assisting U.S. Irrigation Districts and other entities in applying for and being certified for the $40 million of the funding available on the U.S. side of the border. Similar to their efforts on the legislation-authorized projects, Texas Agricultural Experiment Station and Texas Cooperative Extension economists and engineers are collaborating with Rio Grande Basin irrigation district managers, their consulting engineers, the BECC, and NADBank and using RGIDECON© to develop supportive materials documenting the sustainability of the projects being proposed by Texas Irrigation Districts to BECC and NADBank.

The Bureau of Reclamation, in a letter dated July 24, 2002 (Walkoviak), indicated that RGIDECON© satisfies the legislation authorizing projects and that the Bureau will use the results for economic and energy evaluation. Subsequently, discussions with NADBank and BECC management indicate these analyses are adequate and acceptable for documenting the sustainability aspects of the Districts' Stage 1 and 2 submissions.

About the Authors

M. Edward Rister
Ronald D. Lacewell
Allen W. Sturdivant
John R. C. Robinson
Michael C. Popp
John R. Ellis

The authors are Rister, Professor and Associate Head, Department of Agricultural Economics, Texas A&M University and Texas Agricultural Experiment Station, College Station, TX.; Lacewell, Professor and Assistant Vice Chancellor, Department of Agricultural Economics, Texas Agricultural Experiment Station and Texas Cooperative Extension, College Station, TX.; Sturdivant, Extension Associate, Department of Agricultural Economics, Texas Cooperative Extension, Agricultural Research and Extension Center, Weslaco, TX.; Robinson, Associate Professor, Department of Agricultural Economics, Texas Cooperative Extension, Agricultural Research and Extension Center, Weslaco, TX.; Popp, Student Technician, Department of Agricultural Economics, Texas Cooperative Extension, College Station, TX.; and Ellis, former Associate Research Scientist, Department of Agricultural Economics, Texas Agricultural Experiment Station, College Station, TX.

Acknowledgments

Many individuals have contributed to the methodology developed for the Rio Grande Basin Irrigation District economic analyses as described herein. We gratefully acknowledge and appreciate the input and assistance of the following:

- ***Wayne Halbert, George Carpenter, Sonia Kaniger, Bill Friend, Rick Smith, and Edd Fifer.*** These irrigation district managers have been and are a continual source of information, support, and inspiration as we work to develop an accurate, consistent, logical, efficient, and practical analytical approach for these investigations;

- ***Al Blair and Larry Smith.*** These private consulting engineers have substantiated and extended the insights of the irrigation district managers, thereby strengthening the rigor of our methodology and enhancing the integrity of the data;

- ***Guy Fipps and Eric Leigh.*** These agricultural engineers and our colleagues in the Department of Biological and Agricultural Engineering at Texas A&M University and in the Texas Cooperative Extension have provided an extensive amount of background information, contacts, and wisdom;

- ***Jose Amador and Ari Michelsen.*** These Resident Directors of the Agricultural Research and Extension Centers at Weslaco and El Paso, respectively, have been very supportive in identifying contacts, alerting us to critical issues, and arranging meetings, among other collaboration efforts;

- ***Bob Hamilton and Randy Christopherson.*** These economists affiliated with the Bureau of Reclamation have served as reviewers of our methodology. They have also identified appropriate means of satisfying the data requirements specified in the legislative-mandated Bureau of Reclamation Guidelines for Public Law 106-576 authorizing the projects being analyzed, while also assuring principles of economics and finance are met;

- ***Ron Griffin.*** A Resource Economist in the Department of Agricultural Economics at Texas A&M University, Ron has provided insights regarding relevant resource issues, methods for appraising capital water-related projects, and observations on Texas water issues in general;

- ***John Penson and Danny Klinefelter.*** These agricultural economists specializing in finance in the Department of Agricultural Economics at Texas A&M University have served as mentors through our development of the methodology. They have been an excellent sounding board, reacting to an assortment of questions, ideas, and innovative applications of finance methods;

- ***Larry Walkoviak, Rick Clark, Mike Irlbeck, Thomas Michalewicz, and James Allard.*** These individuals are all affiliated with the Bureau of Reclamation in various management roles. They have been instrumental in fostering a collaborative environment in which the several agencies involved in this effort can mutually fulfill their varied responsibilities and conduct the related activities. They have taken the lead in bringing the Texas Water Development Board into planning and facilitating cooperation across State and Federal agencies;

- ***Danny Fox, Debbie Helstrom, Jeff Walker, and Nick Palacios.*** These engineers with the Texas Water Development Board (TWDB) have provided valuable feedback on the methodology and data, as well as insights on accommodating the requirements imposed by the TWDB on the irrigation districts in association with their receipt and use of State Energy Conservation Office (SECO) funding for the development of their project proposals;

- ***Allan Jones and B. L. Harris.*** As Director and Executive Director of the Texas Water Resources Institute, respectively, they provide leadership and oversight for the Rio Grande Basin Initiative funded through a grant from Cooperative State Research, Education, and Extension Service, U.S. Department of Agriculture;

- ***Megan Stubbs.*** An undergraduate in the Department of Agricultural Economics at Texas A&M University, Megan contributed several insightful, thought-provoking comments while reviewing and editing this report and during development of related materials on Rio Grande Basin irrigation districts;

- ***Jason Morris.*** A Student Technician in the Department of Agricultural Economics at Texas A&M University, Jason has provided daily support in the form of computer hardware and software assistance, Internet-based data searches, and other bolstering activities; and

- ***Michele Zinn.*** She is the glue that binds it all together! An Administrative Assistant in the Department of Agricultural Economics and in the Texas Agricultural Experiment Station at Texas A&M University, Michele assists in coordinating daily activities and travel, and provides editorial assistance during manuscript preparation.

Thanks to each and every individual noted above. Nonetheless, we, the authors of this manuscript, accept all responsibilities for any errors, omissions, and/or other oversights that are present in the manuscript and/or the economic spreadsheet model, RGIDECON©.

MER
RDL
AWS
JRCR
MCP
JRE

Table of Contents

Table of Contents, continued.

Table of Contents, continued.

Table of Contents, continued.

List of Exhibits

List of Tables

List of Tables, continued.

List of Tables, continued.

List of Tables, continued.

List of Tables, continued.

Table		Page

List of Tables, continued.

List of Tables, continued.

Economic and Conservation Evaluation of Capital Renovation Projects: Harlingen Irrigation District Cameron County No. 1 – Canal Meters and Telemetry Equipment, Impervious-Lining of Delivery Canals, Pipelines Replacing Delivery Canals, and On-Farm Delivery-Site Meters

Abstract

Initial construction costs and net annual changes in operating and maintenance expenses are identified for the capital renovation project proposed by Harlingen Irrigation District Cameron County No. 1 to the North American Development Bank (NADBank). Both nominal and real, expected economic and financial costs of water and energy savings are identified throughout the anticipated useful lives for each of the four components of the proposed project (i.e., canal meters and telemetry equipment, impervious-lining of delivery canals, 24" pipelines replacing delivery canals, and on-farm delivery-site meters). Sensitivity results for both the cost of water savings and cost of energy savings are presented for several important parameters. Expected cost of water savings and cost of energy savings for each of the four components are aggregated into a composite set of cost measures for the total proposed project. Aggregate cost of water savings is estimated to be **$31.37 per ac-ft** and energy savings are measured at an aggregate value of **$0.0002253 per BTU (i.e., $0.769 per kwh)**. In addition, expected values are indicated for the Bureau of Reclamation's three principal evaluation measures specified in the Public Law 106-576 legislation. The aggregate initial construction cost per ac-ft of water savings measure is $26.87 per ac-ft of water savings. The aggregate initial construction cost per BTU (kwh) of energy savings measure is $0.0001603 per BTU ($0.547 per kwh). The amount of initial construction costs per dollar of total annual economic savings is estimated to be -1.30.

Bureau of Reclamation's Endorsement of RGIDECON©

United States Department of the Interior
BUREAU OF RECLAMATION
Great Plains Region
OKLAHOMA - TEXAS AREA OFFICE
300 E. 8th Street, Suite G-169
Austin, Texas 78701-3225

IN REPLY
REFER TO:
TX-Clark
PRJ-8.00

JUL 24 2002

Dr. Ron Lacewell
Department of Agricultural Economics
Texas A&M University
College Station, TX 77843-2124

Subject: Economic Model for Use in Preparing Proposals for Water Conservation and Improvement Projects Under Public Law 106-576.

Dear Dr. Lacewell:

Having reviewed the formulas, calculations, and logic which support the "Economic Methodology for South Texas Irrigation Projects" (Model) developed by the Department of Agricultural Economics at Texas A&M University (TAMU), the Bureau of Reclamation (Reclamation) concludes that the Model adequately addresses the specific economic criteria contained in the *Lower Rio Grande Valley Water Resources Conservation and Improvement Act of 2000* (P. L. 106-576). The results of the Model will fully satisfy the economic and conservation analyses required by the Act and it may be used by any irrigation district or other entity seeking to qualify a project for authorization and/or construction funding under P.L. 106-576.

We express our sincere appreciation to you, your colleagues, and to TAMU for this significant contribution to the efforts to improve the water supply in the Lower Rio Grande Valley.

If we may be of further assistance, please call me at (512) 916-5641.

Sincerely,

M L Martin

Larry Walkoviak
Area Manager

A Century of Water for the West
1902-2002

Economic and Conservation Evaluation of Capital Renovation Projects: Harlingen Irrigation District Cameron County No. 1 – Canal Meters and Telemetry Equipment, Impervious-Lining of Delivery Canals, Pipelines Replacing Delivery Canals, and On-Farm Delivery-Site Meters

Executive Summary

Introduction

Recognizing the seriousness of the water crisis in South Texas, the U.S. Congress enacted Public Law 106-576, entitled "The Lower Rio Grande Valley Water Conservation and Improvement Act of 2000." Therein, Congress authorized investigation into four water conservation projects for irrigation districts relying on the Rio Grande River for their municipal, industrial, and agricultural irrigation supply of water. Harlingen Irrigation District Cameron County No. 1's (i.e., the District) project is included among the four authorized. Project authorization does not guarantee federal funding as several phases of planning, development, evaluation, etc. are necessary before these projects may be approved for financing and construction.

Subsequent to the noted legislation and approval process developed by the U.S. Bureau of Reclamation for evaluating legislation-authorized projects being proposed by Rio Grande Basin Irrigation Districts, the bi-national North American Development Bank (NADBank) announced the availability of an $80 million Water Conservation Fund for funding irrigation projects on both sides of the U.S.-Mexico border. The NADBank also announced a merging of its board with that of the Border Environment Cooperation Commission (BECC), resulting in the latter assuming a facilitation role in assisting U.S. Irrigation Districts and other entities in applying for and being certified for the $40 million available on the U.S. side of the border. Similar to their efforts on the legislation-authorized projects, Texas Agricultural Experiment Station (TAES) and Texas Cooperative Extension (TCE) economists and engineers are collaborating with Rio Grande Basin irrigation district managers, their consulting engineers, the BECC, and NADBank and using RGIDECON© to develop supportive materials documenting the sustainability of the projects being proposed by Texas Irrigation Districts to BECC and NADBank.

The U.S. Bureau of Reclamation, in a letter dated July 24, 2002, indicated that RGIDECON© satisfies the legislation-authorized projects and that the Bureau will use the results for economic and energy evaluation. Subsequently, the BECC has also acknowledged these analyses are adequate and acceptable for the Districts' Stage 1 and 2 submissions.

This report provides documentation of the economic and conservation analysis conducted for the Harlingen Irrigation District Cameron County #1's project proposal toward its Stage 1 certification with BECC. TAES/TCE agricultural economists have developed this analysis report as facilitated by the Rio Grande Basin Initiative and administered by the Texas Water Resources Institute of the Texas A&M University System.

District Description

The District provides water to 38,025 acres of cropland and diverts up to 22,541 acre feet (ac-ft) for residential and commercial water users in the cities of Harlingen, Palm Valley, Rangerville, Primera, Combs, and Los Indios. Recent agricultural water use for the district has ranged from 37,221 ac-ft in 1999 up to 51,685 ac-ft in 2000, with the five-year average at 45,619 ac-ft. Municipal and industry (M&I) water use has been more consistent, ranging from 20,829 ac-ft in 1997 up to 22,641 ac-ft in 2000, with the five-year average at 21,782 ac-ft.

Proposed Project Components

The capital improvement project proposed by the District to BECC and NADBank consists of four distinct and non-related components. Specifically, it includes the installation of:

- 105 canal meters and associated telemetry equipment for monitoring in-system flows at 70 locations throughout the delivery system which will improve management of water-delivery system operations;

- 3.26 miles of impervious-lined delivery canals replacing four segments of currently concrete-lined delivery canals which will reduce seepage losses, improve flow rates, reduce relift requirements, and increase head at diversion points;

- 5.66 miles of 24" pipelines replacing six segments of currently concrete-lined delivery canals which will reduce seepage losses, improve flow rates, reduce relift requirements, and increase head at diversion points; and

- 400 on-farm delivery-site meters which will improve management of water-delivery system operations, facilitate the District's progression toward total volumetric pricing, and promote increased on-farm efficiencies in water use.

Economic and Conservation Analysis Features of RGIDECON©

RGIDECON© is an Excel spreadsheet developed by TAES/TCE economists to investigate the economic and conservation merits of capital renovation projects proposed by Rio Grande Basin Irrigation Districts. RGIDECON© facilitates integration and analysis of information pertaining to proposed projects' costs, productive lives, water and energy savings, and resulting per unit costs of water and energy savings. RGIDECON© simplifies capital budgeting financial analyses of both individual capital components comprising a project and the overall, total project.

Cost Considerations: Initial Construction Costs & Changes in O&M Costs

Two principal types of costs are analyzed for each component: (a) initial capital outlays and (b) changes in annual operating and maintenance (O&M) expenses. Results related to each type of expenditure for each component are presented in following sections.

Anticipated Water and Energy Savings

Annual water and energy savings are calculated for each component separately and also as a combined total across all components. Water savings are comprised of and associated with (a) reductions in Rio Grande River diversions, (b) increased head at farm diversion points, (c) reduced seepage losses in canals, and (d) better management of water flow. Energy savings result because of lessened diversion and relift pumping and are comprised of (a) the amount of energy used for pumping and (b) the cost (value) of such energy.

Cost of Water and Energy Savings

The estimated cost per ac-ft of water saved as well as the estimated cost of energy saved as a result of a project component's inception, purchase, installation, and implementation is analyzed to gauge each proposed project component's merit. Results related to each type of cost for each component are presented in following sections, as well as totals across all components.

Project Components

Discussion pertaining to costs (initial and subsequent annual O&M) and savings for both water and energy is presented below for each component (i.e., canal meters and telemetry equipment, impervious-lining of delivery canals, 24" pipelines replacing delivery canals, and on-farm delivery-site meters) comprising the Harlingen Irrigation District Cameron County No. 1's NADBank project, and then aggregated across all components. With regards to water and energy savings, areas or sources are first identified, with the subsequent discussion quantifying estimates for those sources.

Component #1: Canal Meters and Telemetry Equipment

Component #1 of the District's proposed NADBank project consists of installing 105 permanent meters at 70 locations throughout the District's delivery system. The installation period is projected to take one year with an ensuing expected useful life of 15 years. No losses of operations or otherwise adverse impacts are anticipated during the installation period since this will occur in the off-season.

<u>**Initial and O&M Costs**</u>

The estimated initial capital investment costs total $757,538 ($747,538 is related to the purchase of canal meters and telemetry equipment, and $10,000 is for computer hardware upgrades). Annual O&M expenditures are expected to increase by $114,675 ($84,675 for digital telephone service and replacement of broken parts and batteries, and $30,000 for the salaries of two part-time office personnel) due to the installation. Additionally, no reductions in annual O&M expenditures are anticipated. Therefore, a net increase in annual O&M costs of $114,675 is expected.

<u>Anticipated Water and Energy Savings</u>

Only off-farm water savings (i.e., within-canal delivery system) are predicted to be forthcoming from the canal meters and telemetry equipment with the nominal total being 30,330 ac-ft over the 15-year productive life of this component and the real 2002 total being 21,617 ac-ft. Annual water savings estimates are based on 3% of current annual use. Associated energy savings estimates are 4,304,093,170 BTUs (1,261,457 kwh) in nominal terms over the 15-year productive life and 3,067,600,987 BTUs (899,062 kwh) in real 2002 terms. Energy savings are based on reduced diversions at the Rio Grande River.

<u>Cost of Water and Energy Savings</u>

The economic and financial cost of water savings forthcoming from the canal meters and telemetry equipment is estimated to be $87.60 per ac-ft. This value is obtained by dividing the annuity equivalent of the total net cost stream for water savings from all sources of $188,987 (in 2002 terms) by the annuity equivalent of the total net water savings of 2,157 ac-ft (in 2002 terms). The economic and financial cost of energy savings are estimated at $0.0006466 per BTU ($2.206 per kwh). This value is obtained by dividing the annuity equivalent of the total net cost stream for energy savings from all sources of $197,960 (in 2002 terms) by the annuity equivalent of the total net energy savings of 306,156,742 BTU's (89,729 kwhs) (in 2002 terms).

Component #2: Impervious-Lining of Delivery Canals

Component #2 of the District's proposed NADBank project consists of installing 3.26 miles of impervious-lining in four segments of currently concrete-lined delivery canals. The installation period is projected to take one year with an ensuing expected useful life of 20 years. No losses of operations or otherwise adverse impacts are anticipated during the installation period since this will occur in the off-season.

<u>Initial and O&M Costs</u>

Estimated initial capital investment costs total $696,568. Annual increases in O&M expenditures of $1,304 ($400 per mile of canal receiving the impervious-lining) are expected. Additionally, decreases in annual O&M expenditures of $5,216 ($1,600 per mile of canal receiving the impervious-lining) are anticipated for discontinued maintenance. Therefore, a net decrease in annual O&M costs of $3,912 ($1,200 per mile) is expected.

<u>Anticipated Water and Energy Savings</u>

Both off- and on-farm water savings are predicted to be forthcoming from the 3.26 miles of impervious-lined delivery canals with the nominal total being 29,478 ac-ft over the 20-year productive life of this component and the real 2002 total being 18,343 ac-ft. Annual water savings estimates are based on 215.33 ac-ft per mile of canal receiving the impervious-lining, with an equivalent amount of on-farm water savings also assumed. Associated energy savings estimates are 5,651,015,214 BTUs (1,656,218 kwh) in nominal terms over the 20-year productive life and 3,516,444,182 BTUs (1,030,611 kwh) in real 2002 terms. Energy savings are based on reduced diversions at the Rio Grande River and reduced use of relift pumps within the water-delivery system.

Cost of Water and Energy Savings

The economic and financial cost of water savings forthcoming from the impervious-lined delivery canals is estimated to be $29.17 per ac-ft. This value is obtained by dividing the annuity equivalent of the total net cost stream for water savings from all sources of $45,961 (in 2002 terms) by the annuity equivalent of the total net water savings of 1,576 ac-ft (in 2002 terms). The economic and financial cost of energy savings are estimated at $0.0001824 per BTU ($0.622 per kwh). This value is obtained by dividing the annuity equivalent of the total net cost stream for energy savings from all sources of $55,100 (in 2002 terms) by the annuity equivalent of the total net energy savings of 302,063,806 BTU's (88,529 kwhs) (in 2002 terms).

Component #3: 24" Pipeline Replacing Delivery Canals

Component #3 of the District's proposed NADBank project consists of installing 5.66 miles of 24" pipelines in six segments of currently concrete-lined delivery canals. The installation period is projected to take one year with an ensuing expected useful life of 49 years. No losses of operations or otherwise adverse impacts are anticipated during the installation period since this will occur in the off-season.

Initial and O&M Costs

Estimated initial capital investment costs total $1,106,080 ($195,420 per mile). Annual increases in O&M expenditures of $1,132 ($200 per mile of canal converted to pipeline) are expected. Additionally, decreases in annual O&M expenditures of $9,056 ($1,600 per mile of canal converted to pipeline) are anticipated for discontinued maintenance. Therefore, a net decrease in annual O&M costs of $7,924 ($1,400 per mile) is expected.

Anticipated Water and Energy Savings

Both off- and on-farm water savings are predicted to be forthcoming from the 5.66 miles of 24" pipelines with the nominal total being 119,460 ac-ft over the 49-year productive life of this component and the real 2002 total being 50,029 ac-ft. Annual water savings estimates are based on 215.33 ac-ft per mile of canal converted to pipeline, with an equivalent amount of on-farm water savings also assumed. Associated energy savings estimates are 22,900,676,219 BTUs (6,711,804 kwh) in nominal terms over the 49-year productive life and 9,590,544,355 BTUs (2,810,828 kwh) in real 2002 terms. Energy savings are based on reduced diversions at the Rio Grande River and reduced use of relift pumps within the water-delivery system.

Cost of Water and Energy Savings

The economic and financial cost of water savings forthcoming from the 24" pipelines is estimated to be $13.20 per ac-ft. This value is obtained by dividing the annuity equivalent of the total net cost stream for water savings from all sources of $42,626 (in 2002 terms) by the annuity equivalent of the total net water savings of 3,230 ac-ft (in 2002 terms). The economic and financial cost of energy savings are estimated at $0.0000982 per BTU ($0.335 per kwh). This value is obtained by dividing the annuity equivalent of the total net cost stream for energy savings from all sources of $60,771 (in 2002 terms) by the annuity equivalent of the total net energy savings of 619,107,843 BTU's (181,450 kwhs) (in 2002 terms).

Component #4: On-Farm Delivery-Site Meters

Component #4 of the District's proposed NADBank project consists of installing 400 on-farm delivery-site meters in the District. The installation period is projected to take one year with an ensuing expected useful life of 10 years. No losses of operations or otherwise adverse impacts are anticipated during the installation period since this will occur in the off-season.

Initial and O&M Costs

Estimated initial capital investment costs total $649,816. Annual O&M expenditures are expected to increase by $76,000 (for replacements parts and batteries, servicing, calibration, etc.) due to the installation. Additionally, no reductions in annual O&M expenditures are anticipated. Therefore, a net increase in annual O&M costs of $76,000 is expected.

Anticipated Water and Energy Savings

Only on-farm water savings are predicted to be forthcoming from the 400 on-farm delivery-site meters with the nominal total being 61,585 ac-ft over the 10-year productive life of this component and the real 2002 total being 48,030 ac-ft. Annual water savings estimates are based on 27% of current annual use on 50% of irrigation water. Associated energy savings estimates are 8,739,428,083 BTUs (2,561,380 kwh) in nominal terms over the 10-year productive life and 6,815,825,995 BTUs (1,997,604 kwh) in real 2002 terms.

Cost of Water and Energy Savings

The economic and financial cost of water savings forthcoming from the on-farm delivery-site meters is estimated to be $21.71 per ac-ft. This value is obtained by dividing the annuity equivalent of the total net cost stream for water savings from all sources of $133,063 (in 2002 terms) by the annuity equivalent of the total net water savings of 6,129 ac-ft (in 2002 terms). The economic and financial cost of energy savings are estimated at $0.0001823 per BTU ($0.622 per kwh). This value is obtained by dividing the annuity equivalent of the total net cost stream for energy savings from all sources of $158,533 (in 2002 terms) by the annuity equivalent of the total net energy savings of 869,731,963 BTU's (254,903 kwhs) (in 2002 terms).

Totals Across All Components

The methodology used in evaluating the economic and conservation potential of the proposed project and the respective individual components accounts for timing of inflows and outflows of funds and the anticipated installation and productive time periods of the investments. The cost measures calculated for the individual components are first converted into 'annuity equivalents,' prior to being aggregated into the comprehensive measures. The 'annuity equivalent' calculations facilitate comparison and aggregation of capital projects with unequal useful lives, effectively serving as development of a common denominator. The finance aspect of the 'annuity equivalent' calculation as it is used in the RGIDECON© analyses is such that it represents an annual cost savings associated with one unit of water (or energy) each year extended indefinitely into the future. Zero salvage values and continual replacement of the respective technologies (i.e., canal meters and telemetry equipment, impervious-lining of delivery canals, 24" pipelines replacing delivery canals, and on-farm delivery-site meters) with similar capital items as their useful life ends are assumed.

Initial and O&M Costs

The total capital investment costs required for all projects amounts to $3,209,999. Combining these costs with the projected changes in annual O&M expenditures and the useful lives of the respective project components results in an annuity equivalent of $410,637 costs per year for water savings associated with the total project. The similar measure for costs of energy savings is $472,384 per year.

Anticipated Water and Energy Savings

Both off- and on-farm water savings are expected from the four components with the nominal total being 240,853 ac-ft over their expected productive lives and the real 2002 total being 138,019 ac-ft. On an average annual basis (or annuity equivalent basis), this amounts to 13,092 ac-ft across the four project components. Annual water savings estimates are based on reduced seepage, improved water-delivery system management, and increased on-farm efficiency. Associated energy savings estimates are 41,595,212,685 BTUs (12,190,860 kwh) in nominal terms over their lives and 22,990,415,520 BTUs (6,738,105 kwh) in real 2002 terms. On an average annual basis (or annuity equivalent basis), this amounts to 2,097,060,355 BTUs (614,613 kwhs) across the four project components. Energy savings are based on reduced diversions at the Rio Grande River and reduced relift pumping in the District's delivery system.

Cost of Water and Energy Savings

The aggregation of the economic and financial costs of water and energy savings for the individual project components into cost measures for the total comprehensive project result in estimates of **$31.37 per ac-ft** cost of water savings and **$0.0002253 per BTU ($0.769 per kwh)** cost of energy savings.

Summary

The following table summarizes key information regarding each of the components of Harlingen Irrigation District, Cameron County #1's NADBank project, with a more complete discussion provided in the text of the complete report.

Sensitivity Analyses

Sensitivity results for both the costs of water and energy savings are presented within the main text whereby two parameters are varied with all others remaining constant. This permits testing of the stability (or instability) of key input values and shows how sensitive results are to variances in other input factors. Key variables subjected to sensitivity analysis include (a) the amount of reduction in Rio Grande River diversions, (b) the expected useful life of the investment, (c) the initial capital investment cost, (d) the value of BTU savings (i.e., cost of energy), and (e) the amount of energy savings estimated.

Table ES1. Summary of Component Data and Economic and Conservation Analyses Results for Harlingen Irrigation District Cameron County No. 1's NADBank Project, 2002.

	Project Component				
	Canal Meters & Telemetry Equipment	Impervious –Lined Delivery Canals	24" Pipelines Replacing Delivery Canals	On-Farm Delivery-Site Meters	Aggregate
Initial Investment Cost ($)	$757,538	$696,565	$1,106,080	$649,816	$3,209,999
Expected Useful Life (years)	15	20	49	10	n/a
Net Changes in Annual O&M ($)	$114,675	($3,912)	($7,924)	$76,000	$188,839
Annuity Equivalent of Net Cost Stream – Water Savings ($/yr)	$ 188,987	$ 45,961	$ 42,626	$ 133,063	$ 410,637
Annuity Equivalent of Water Savings (ac-ft)	2,157	1,576	3,230	6,129	13,092
Calculated Cost of Water Savings ($/ac-ft)	**$87.60**	**$29.17**	**$13.20**	**$21.71**	**$31.37**
Annuity Equivalent of Net Cost Stream – Energy Savings ($/yr)	$ 197,960	$ 55,100	$ 60,771	$ 158,553	$ 472,384
Annuity Equivalent of Energy Savings (BTUs)	306,156,742	302,063,806	619,107,843	869,731,963	2,097,060,355
Annuity Equivalent of Energy Savings (kwhs)	89,729	88,529	181,450	254,903	614,613
Calculated Cost of Energy Savings ($/BTU)	**$0.0006466**	**$0.0001824**	**$0.0000982**	**$0.0001823**	**$0.0002253**
Calculated Cost of Energy Savings ($/kwh)	**$2.206**	**$0.622**	**$0.335**	**$0.622**	**$0.769**

Legislative Criteria

Public Law 106-576 requires three economic measures be calculated and included as part of the information prepared for the Bureau of Reclamation's evaluation of the proposed projects. According to the U.S. Bureau of Reclamation, these measures are more often stated in their inverse mode:

- Dollars of construction cost per ac-ft of water saved;
- Dollars of construction cost per BTU (and kwh) of energy saved; and
- Dollars of construction cost per dollar of annual economic savings.

The noted legislated criteria involve a series of calculations similar to, but different from those used in developing the cost measures cited in the main body of the full analysis report. Principal differences consist of the legislated criteria not requiring aggregation of the initial capital investment costs with the annual changes in O&M expenditures, but rather entailing separate sets of calculations for each type of costs relative to the anticipated water and energy savings. The approach used in aggregating the legislated criteria results presented in Appendix A into one set of uniform measures utilizes the present value methods followed in the calculation of the economic and financial results reported in the main body of the text, but does not include the development of annuity equivalent measures. These compromises in approaches are intended to maintain the spirit of the legislated criteria's intentions. Only real, present value measures are presented and discussed for the legislated criteria aggregate results, thereby designating all such values in terms of 2002 equivalents. **Differences in useful lives across project components are not fully represented, however, in these calculated values.**

The aggregate initial construction costs per ac-ft of water savings measure is $26.87 per ac-ft of water savings which is lower than the comprehensive economic and financial value of **$31.37 per ac-ft** identified and discussed in the main body of the analysis report. The differences in these values are attributable to the incorporation of both initial capital costs and changes in operating expenses in the latter value, and its treatment of the differences in the useful lives of the respective components of the proposed project.

The aggregate initial construction cost per BTU (kwh) of energy savings measure is $0.000160 per BTU ($0.55 per kwh). These cost estimates are lower than the **$0.0002253 per BTU ($0.769 per kwh)** comprehensive economic and financial cost estimates identified for reasons similar to those noted above with respect to the estimates for costs of water savings.

The final aggregate legislated criterion of interest is the amount of initial construction costs per dollar of total annual economic savings. The estimate for this ratio measure is -1.30, indicating that (a) the net change in annual O&M expenditures is negative, i.e., a reduction in O&M expenditures is anticipated; and (b) $1.30 of initial construction costs are expended for each such dollar reduction in O&M expenditures, with the latter represented in total real dollars accrued across the four project components' respective planning periods.

Economic and Conservation Evaluation of Capital Renovation Projects: Harlingen Irrigation District Cameron County No. 1 – Canal Meters and Telemetry Equipment, Impervious-Lining of Delivery Canals, Pipelines Replacing Delivery Canals, and On-Farm Delivery-Site Meters

Introduction

Harlingen Irrigation District Cameron County No. 1 is included among the four irrigation districts authorized for water conservation projects in the Lower Rio Grande Valley Water Resources Conservation and Improvement Act of 2000 (Act), or Public Law (PL) 106-576. As stated in the legislation, "If the Secretary determines that ... meet[s] the review criteria and project requirements, as set forth in section 3 [of the Act], the Secretary may conduct or participate in funding engineering work, infrastructure construction, and improvements for the purpose of conserving and transporting raw water through that project" (United States Public Law 106-576). This report provides documentation of an economic and conservation analysis conducted for the four components (i.e., canal meters and telemetry equipment, impervious-lining of delivery canals, 24" pipelines replacing delivery canals, and on-farm delivery-site meters) comprising the Harlingen Irrigation District Cameron County No. 1 (the District) project proposed to the Border Environment Cooperation Commission (BECC) and the North American Development Bank (NADBank) during the Fall of 2002.

Irrigation District Description[1]

Twenty-eight irrigation districts exist in the Texas Lower Rio Grande Valley (**Exhibit 1**).[2] The Harlingen Irrigation District Cameron County No. 1 (the District) office is located in the heart of Harlingen, Texas (**Exhibits 2** and **3**). The District boundary covers 56,114 acres of Cameron County (**Exhibit 4**). Postal and street addresses are P.O. Box 148, 301 E. Pierce, Harlingen, TX 78551. Telephone contact information is 956/423-7015 and the fax number is 956/423-4671.

---

1 The general descriptive information presented for the Harlingen Irrigation District Cameron County No. 1 was assimilated from several sources, including documents provided by Wayne Halbert (the District manager), the IDEA web site maintained by Guy Fipps and his staff in the Department of Biological and Agricultural Engineering at Texas A&M University, College Station, Texas, the Project Plan for this project (AWBLAIR ENGINEERING), Harlingen Irrigation District Cameron County No. 1's Step 1 submissions (2002a and 2002b) to the Border Environment Cooperation Commission (BECC), the BECC's Project Strategic Plan for Harlingen Irrigation District Cameron County No. 1, and the Region M Rio Grande Regional Water Planning Group report.

2 Exhibits and Tables are presented at the end of the report, after the References and the Glossary and before the Appendices.

Wayne Halbert is the General Manager of the District. He has held that position since 1989. Previously, he farmed in the area, an interest he continues. Al Blair of AWBlair Engineering, Dripping Springs, TX, is the consulting engineer for this project.

The District provides water to 38,025 acres of cropland and holds a certificate of adjudication for 39,574 acres of class A water rights. The District also diverts up to 22,541 ac-ft of water that is designated for delivery by the District to municipalities. The District also diverts another 4,692 ac-ft of water that is designated for domestic users in rural areas within the District. The maximum allocation of water usable per annum is 98,232.5 acre-feet (ac-ft).

There are 3,309 accounts serviced in the District. The majority of acreage is serviced under individual water orders as needed. Also included are annual permits for 30 accounts for orchards and commercial nurseries that use drip or micro-emitter systems. Lastly, 500 accounts exist for lawn watering, golf courses, parks, school yards, and ponds.

Irrigated Acreage and Major Crops

Furrow irrigation accounts for 95% of irrigation deliveries. Special turnout connections for polypipe are supplied to customers free of charge, with 60% of the District having converted to polypipe. Flood irrigation is the norm for orchards, sugarcane, and pastures. Low pressure pivot systems are being considered for several crop situations. The typical crop mix across the District is noted in **Table 1**, which illustrates the relative importance of grain sorghum, cotton, and sugarcane on an acreage-demand basis. It is notable that the crop mix distribution within a particular irrigation district and/or area of the Lower Rio Grande Valley may vary considerably across areas depending on output prices and the relative available local water supplies. In water-short years, sugarcane acreage, although a perennial crop, may "migrate" to districts and/or areas appearing to be water-rich, in a relative sense.

Municipalities Served

The District diverts up to 22,541 ac-ft for residential and commercial water users, including the cities of Harlingen, Palm Valley, Rangerville, Primera, Combs, and Los Indios (**Exhibit 5**). The needs of these users are first on a priority basis within the District. With that noted, it is important to note that residential and commercial users[3,4] are dependent on an adequate water supply to fully charge the District's delivery system, providing "push water" for facilitating delivery of their water from the Rio Grande River diversion point to the municipal delivery sites. In the absence of such a fully charged system due to constrained allocations associated with low

---

3 Hereafter, residential and commercial users are referred to as "M&I" (or Municipal & Industrial), terms more widely used in irrigation district operations.

4 Technically, there are currently no industrial users of water provided by the Harlingen Irrigation District Cameron County No. 1 (Blair), i.e., all non-agricultural water use is associated with municipalities. To maintain consistency of style across analyses and reports for the different districts, however, all non-agricultural water use is referred to as M&I in this and other related reports as a matter of convention.

reservoir levels, M&I users will require additional water-rights purchases and/or leases to facilitate the delivery process.

Historic Water Use

The most recent five years (1997-2001) demonstrate a range of water use in the District (**Table 2**). Agricultural use has ranged from 37,221 ac-ft in 1999 up to 51,685 ac-ft in 2000; the five-year average is 45,619 ac-ft. M&I use is more consistent, ranging from 20,829 ac-ft in 1997 up to 22,641 ac-ft in 2000; the five-year average is 21,782 ac-ft. The average total water diverted within the District during 1997-2001 is 67,401 ac-ft, with the range being 59,261 ac-ft in 1999 up to 74,326 ac-ft in 2000.

Assessment of Technology and Efficiency Status

The main pumping plant feeds out of the Rio Grande River near the city of Los Indios (**Exhibit 5**). The facility was built in the 1920's and has a current operating capacity of 470 cfs with a typical peak-pumping rate of 410 cfs. More than 155 miles of pipelines, 57 miles of main canals, 55 relift pumping stations, and three storage reservoirs totaling a volume of 1,380 ac-ft comprise the District's delivery system infrastructure.

The District has been aggressive in increasing the maximum amount of water deliverable to each turnout while also increasing its overall efficiency by reducing irrigation time requirements. Experimenting with traditional turnout metering devices has revealed several problems: (1) restriction of flow; (2) fouling of meter devices; (3) high meter failures and excessive maintenance due to temporary status; and (4) high cost of monitoring and servicing.

The District has a Geographic Information System (GIS) linking a mapping system to a data base, indicating: where water has been ordered; for what types of crops; and various systems necessary to deliver the water. Volumetric pricing in water deliveries has become more acceptable, with approximately 50 percent of current agricultural water use volumetrically measured. Alternatives for measuring water diversions are being considered. Producers' use of polypipe is encouraged.

Water Rights Ownership and Sales

The District holds Certificate of Adjudication No. 23-831. The residential and commercial users' water rights belong to the respective municipal communities. Users interested in acquiring additional water beyond their available allocations may acquire such water from parties interested in selling or leasing rights. Such purchases and/or leases are subject to a transportation delivery loss charged by the District; that is, purchase or lease of one ac-ft of water from sources inside or outside the District will result in users receiving some amount less than one ac-ft at their diversion point.

Water charges assessed irrigators within the District consist of an annual maintenance and operations fee assessment of $9 per irrigated acre paid for by the landowner. An additional $6 per acre per irrigation is paid for by water users (i.e., either the landowner-operator or tenant-producer), with such irrigations approximated at 0.5 ac-ft per acre (Halbert).

In the event of water supplies exceeding demands within the District, current District policy is to sell annual water supplies, even on long-term agreement, rather than toward a one-time sale of water rights (Halbert). The District has control over the irrigation water supplies, but the municipal rights holders control and realize any benefits accruing from sale or lease of their rights.

Project Data

As proposed by the District, the capital improvements for this project consist of four distinct and non-related, independent components, i.e., there are no anticipated direct synergies among the four components. The four components of the total project are (1) canal meters and telemetry equipment, (2) impervious-lining of delivery canals, (3) 24" pipelines replacing delivery canals, and (4) on-farm delivery-site meters.

Component #1 – Canal Meters and Telemetry Equipment

Summary data for the first component of the District's proposed project, canal meters and telemetry equipment, are presented in **Table 3.** Discussion of that data follows.

Description

This project component consists of installing 105 meters at 70 locations throughout the District delivery system (**Table 3**) (Blair). Specifically, meters and telemetry equipment will be installed at each of the numerous pump sites where pressure is increased to operate pipelines and at canal division points in the District. Meters comprising this project component are installed at intermediate transport points in the canal delivery system rather than at farm delivery points (the latter is component #4 of this proposed project). The meter devices will be permanent installations and send data via telemetry to the District office for direct input into a GIS database system. The installation of permanent meters will be more stable and require less maintenance than portable meters. The number of meter devices installed at each site will typically vary between one and three.

The information generated by the meters and telemetry system will provide flow data needed to balance the distribution of water within the delivery canals. That is, information will be generated regarding what areas are being irrigated and how much water is being supplied to these areas. The resulting improved management will minimize the over-delivery of water (i.e., waste), which has been estimated at 40%. Associated energy savings also would be realized with the reduced pumping requirements. Individual growers will be unhampered by the associated reduction in restriction of flows associated with the permanent meters. The benefits relate to operation of the District and increased efficiency in managing Rio Grande River diversions and deliveries to both agricultural and M&I users, with each of these advantages being of an “off-farm” nature.

Installation Period

It is anticipated that it will take one year after project component initiation and purchase of the meters, telemetry equipment, and other associated capital assets to accomplish installation, integration into the management information system, and full implementation of the complete package of canal meters and telemetry equipment (**Table 3**). No losses of operations or otherwise adverse impacts are anticipated during the installation period (Halbert; Blair).

Productive Period

A useful life of 15 years for the canal meters and telemetry equipment is expected and assumed in the baseline analysis (**Table 3**). A shorter-useful life is possible with the advent of new, more effective technology. The 15-year estimate is reasonable and consistent, however, with prior observations in other locales (Blair). Sensitivity analyses are utilized to examine the effects of this assumption. The first year of the productive period is assumed to occur during year two of the 16-year planning period.

Costs

Two principal types of costs are of consequence when evaluating this proposed investment: (a) the initial capital outlay and (b) recurring operating and maintenance (O&M) expenses. Assumptions related to each type of expenditure are presented below.

Initial. Based on discussions with Bureau of Reclamation management (Clark et al. 2002a), expenses associated with design, engineering, and other preliminary development of the project component's proposal are ignored in the economic analysis prepared for the planning report. Such costs are to be incorporated, however, into the materials associated with the final design phase of the project component.

Capital investment costs during the installation stage of this project component total $747,538 in 2002 nominal dollars. Of that total, $737,538 is related to purchase of the meters and associated telemetry equipment (Blair). The remaining $10,000 is for upgrades in computer hardware in the District office to facilitate usefulness of the increase in data and information forthcoming from the meters (Fipps 2001-2002). Sensitivity analyses on the total amount of all capital expenditures are utilized to examine the effects of these assumptions. All such expenditures are assumed to occur on day one of this project component's inception, avoiding the need to account for inflation in the cost estimates.

Recurring. Annual increases in O&M expenditures are expected to total $114,675 in 2002 nominal dollars (**Table 3**). Such expenses will commence during year two of the planning horizon and be indexed to account for expected inflation through the end of each year of the productive period. There are two dimensions of these expected increases in annual O&M expenditures: (a) $84,675 for digital telephone service and maintenance costs for replacement of broken parts and batteries (Halbert; Blair); and (b) $30,000 for two part-time office personnel to manage and/or operate the management information system aspects of this proposed component (Fipps 2001-2002).

Projected Savings

Water. Water savings of interest are reductions in diversions from the Rio Grande River, i.e., how much less water will be used by the District as a result of this project component's purchase, installation, and utilization? Estimates of such savings are comprised, in this case, of only off-farm savings with regards to agricultural (i.e., irrigation) water use and off-farm savings related to M&I water use, i.e., there are no on-farm savings anticipated directly attributable to the canal meters and telemetry equipment investment.

Off-farm savings are those occurring in the District's canal delivery system as a result of better management of water flow toward areas of the District requiring water at a given time and away from those areas not needing it at a particular time, e.g., reducing "spills" occurring due to over-deliveries, and minimizing "over-ordering" as a means to insure adequate supplies. Knowledge of area and sub-area demands, gate management, and flow monitoring are an integrated package of information necessary to achieve improved efficiency in water utilization and resulting water savings.

Expected reductions in Rio Grande River diversions affiliated with off-farm water use are conservatively estimated at 3% of current use for both irrigation and M&I (Blair). The five-year (1997-2001) average irrigation water use in the District is 45,619 ac-ft (**Table 2**). Three percent of that quantity of water amounts to 1,368.6 ac-ft of savings annually (**Table 3**). The five-year (1997-2001) average M&I water use in the District is 21,782 ac-ft (**Table 2**). Three percent of that quantity of water amounts to 653.5 ac-ft of savings annually (**Table 3**). The total anticipated annual water savings forthcoming from the investment in and operation of the canal meters and telemetry equipment capital assets is thus 2,022.1 ac-ft (**Table 3**).

Although it would be reasonable to assume annual savings would increase through this project component's duration (at least up to some maximum higher level) as a result of increasing management knowledge and abilities related to the use of the enhanced water flow and usage information, the level of savings is held constant each year to provide for a conservative analysis. Sensitivity analyses are utilized to examine the effects of this assumption.

Energy. Energy savings may occur as a result of less water being pumped at the Rio Grande River diversion site and also because of lower relift pumping requirements at one or more points throughout the canal delivery system. The amount of such energy savings and the associated monetary savings are detailed below.

Factors constituting energy savings associated with lessened diversion pumping are twofold: (a) amount of energy used for pumping and (b) the cost (value) of such energy. Recent energy records for the District are presented in **Table 4.** On average, 141,907.5 BTUs were used to pump each ac-ft of water used in the District during 2001 (Halbert). This value, in conjunction with the anticipated annual irrigation water savings off-farm totaling 1,368.6 ac-ft, infers anticipated annual irrigation energy savings of 194,209,513 BTUs (i.e., 56,920 kwh[5]) (**Table 3**).

---

[5] There are 3,412 BTUs in one kwh (Infoplease.com).

Similarly, the noted BTU usage level in conjunction with the anticipated annual M&I water savings off-farm totaling 653.5 ac-ft infers anticipated annual M&I energy savings of 92,730,032 BTUs (27,178 kwh) (**Table 3**). Assuming a $0.10 cost per kwh,[6] the estimated annual irrigation energy cost savings are $5,692 and the annual M&I energy cost savings are $2,718 (**Table 3**). Sensitivity analyses are utilized to examine the effects of the assumptions for both the amount of energy used per ac-ft of water pumped and the cost per unit of energy.

No changes in relift pumping operations are anticipated in association with this project component. Thus, there are no additional energy savings to be tallied.

Operating and Maintenance. No reductions in O&M expenditures are anticipated for this project component (**Table 3**). Consequently, there is no claim in this respect as a credit against the costs of this project component.

Reclaimed Property. No real property will be reclaimed in association with this project component (**Table 3**). Consequently, there is no realizable cash income to claim as a credit against the costs of this project component.

Component #2 -- Impervious-Lining of Delivery Canals

Summary data for the second component of the District's proposed project, impervious-lining of currently concrete-lined delivery canals, are presented in **Table 5.** Discussion of that data follows.

Description

This project component consists of impervious-lining sections of four delivery canal segments (i.e., Bowman A and Wyrick A, B, and C) which are currently concrete-lined and have significant seepage problems (**Table 5; Table 6**). Impervious-lining of 3.26 miles of currently concrete-lined delivery canals is expected to:

a) eliminate seepage estimated at 215.33 ac-ft/mile (Fipps 2000) (**Table 5**);
b) allow for the removal of a lock system and eliminate the need for several pumping stations; and
c) provide several secondary benefits, including increased flows to individual farms due to increased head and/or allowing greater number of farms to be irrigated simultaneously, reducing the travel time and expense of the canal operators.

---

6 Energy costs during the period and for the various pumps monitored ranged from $0.08 to 0.125 per kwh (Halbert). The $0.10 level was assumed as an average, mid-range cost.

Installation Period

It is anticipated that it will take one year after purchase and project component initiation for the impervious canal lining to be installed and its use to be fully implemented (**Table 5**). No losses of operations or otherwise adverse impacts are anticipated during the installation period since this will occur in the off-season (Halbert; Blair).

Productive Period

A useful life of 20 years for the impervious-lined delivery canals is expected and assumed in the baseline analysis (**Table 5**). A shorter-useful life is possible with the advent of new, more effective technology. The 20-year estimate is reasonable and consistent, however, with prior observations in other locales (Blair). Sensitivity analyses are utilized to examine the effects of this assumption. The first year of the productive period is assumed to occur during year 2 of the 21-year planning period.

Costs

Two principal types of costs are of consequence when evaluating this proposed investment: (a) the initial capital outlay and (b) recurring operating and maintenance expenses. Assumptions related to each type of expenditure are presented below.

Initial. Based on discussions with Bureau of Reclamation management, expenses associated with design, engineering, and other preliminary development of this project component's proposal are ignored in the economic analysis prepared for the planning report. Such costs are, however, to be incorporated into the materials associated with the final design phase of this project component.

Capital investment costs during the installation stage of this project component total $1,696,565 in 2002 nominal dollars (**Table 5**). The total amount is related to purchase and installation of the 3.26 miles of impervious canal lining (Blair). Sensitivity analyses on the total amount of all capital expenditures are utilized to examine the effects of this assumption. Combined with the calculated 275,150 total square footage of impervious-lining material identified in **Table 6**, this magnitude of capital cost translates into an estimated initial construction cost of $2.53 per square foot of impervious-lining material (or $213,705 per linear mile). Certainly there are less-expensive materials on the market today compared to when these estimates were determined (Blair; Halbert). Dynamics of the economy and technologically advances consolidated with questions regarding the relative costs, useful lives, and durability of alternative materials contribute, however, to uncertainty of the exact costs of this project component. It is anticipated that the noted costs are probably higher than what the actual costs will be, but this value provides for a conservative analysis (Halbert; Blair). All such expenditures are assumed to occur on day one of this project component's inception, avoiding the need to account for inflation in the cost estimates.

Recurring. This analysis focuses on marginal changes in the District's operations, water savings, and energy savings forthcoming from the proposed project and its several components.

In this case, O&M expenditures associated with the impervious-lined delivery canals are perceived to be of a different nature than those presently occurring for the concrete-lined delivery canals. Annual operating and maintenance (O&M) expenditures associated with the affected segments of the canal delivery system are anticipated to be $400 per mile of impervious-lined canal, or a total of $1,304 (**Table 5**). Any O&M requirements during the first two years following installation of the impervious-lining are assumed to be covered by warranty (Blair).

Projected Savings

Water. Water savings are reductions in diversions from the Rio Grande River, i.e., how much less water will be used by the District as a result of this project component's installation and utilization? Estimates of such savings are comprised, in this case, of both off-farm and on-farm savings with regards to agricultural (i.e., irrigation) water use only; i.e., no savings related to M&I water use are anticipated.

Off-farm savings are those occurring in the District's canal delivery system as a result of fewer leaks after the targeted canal segments are lined with impervious material. Historic ponding test studies in the District by Fipps (2000) documenting water losses on concrete-lined canal segments similar to the ones proposed for impervious-lining, in comparable soil series, indicate annual losses are 215.33 ac-ft of water per mile of canal.[7] It is assumed here such losses will translate into savings at a 100% rate if the canals are lined with impervious material, i.e., all 215.33 ac-ft per mile of present losses will be saved. Fipps' estimates are admittedly applicable to the canal systems in their present state; additional deterioration and increased water losses and associated increases in O&M expenses should be expected as the respective segments age (Halbert; Carpenter). While mathematical representation of alternative time paths of such phenomena could be developed, the analysis is conservatively constrained to assuming a constant 215.33 ac-ft of annual water savings per mile of concrete-lined canal that is lined with impervious material (Blair).[8]

The expected reductions in Rio Grande River diversions affiliated with off-farm water use are thus conservatively estimated at 215.33 acre-ft per mile for the 3.26 of currently concrete-lined delivery canals proposed for impervious-lining (**Table 6**). Such annual water savings total 701.9 ac-ft of water (**Table 5**). Sensitivity analyses are utilized to examine the effects of the 215.33 ac-ft per mile off-farm water-savings assumption.

Additional on-farm savings are expected in association with irrigation water use as a result of increased head at farm diversion points, allowing for faster irrigation of fields and resulting

---

7 Such studies did not include replications accounting for variance of canal depth, width, etc. (Fipps 2000). The estimates are the best available, however, recognizing time and monetary constraints relative to the costs of this project component.

8 A few experimental analyses indicated the obvious – allowing for increased water losses over time as the current concrete-lined delivery canals aged and recognizing that such increased future losses translate into greater potential savings accruing to the proposed impervious-lining project component resulted in substantial reductions in the costs per ac-ft of water savings and per BTU/kwh of energy savings.

lower levels of percolation losses (Lewis and Milne). On-farm savings are assumed here to equal off-farm savings (Blair).[9] The annual amount of such on-farm savings in the base analysis is thus 701.9 ac-ft (**Table 5**). As with the other estimated water savings, these savings are held constant each year of the impervious-lining's productive period to provide for a conservative analysis. Combining off- and on-farm water savings results in 1,403.7 ac-ft per year. The on-farm savings estimates are directly linked to the assumed off-farm savings value, allowing for direct variance during the sensitivity analyses of water savings per mile of impervious-lined canal.

Energy. Energy savings may occur as a result of less water being pumped at the Rio Grande River diversion site and also because of lower relift pumping requirements at one or more points throughout the canal delivery system. The amount of such energy savings and the associated monetary savings are detailed below.

Factors constituting energy savings associated with lessened diversion pumping are twofold: (a) less energy used for pumping and (b) the cost (value) of such energy. Recent historic records for the District are presented in **Table 4.** On average, 141,907.5 BTUs were used to pump each ac-ft of water used in the District during 2001. This value, in conjunction with the anticipated annual irrigation water savings off-farm totaling 701.9 ac-ft, infers anticipated annual irrigation energy savings of 99,599,435 BTUs (29,191 kwh) (**Table 5**). Assuming a $0.10 cost per kwh, the estimated annual irrigation energy cost savings are $2,919 in 2002 dollars (**Table 5**). Similar savings are anticipated for the assumed on-farm reductions in water use. Sensitivity analyses are utilized to examine the effects of the assumptions for both the amount of energy used per ac-ft of water pumped and the cost per unit of energy.

It is anticipated that the District's relift pumping operations for 40% of the total water use will be affected by project components #s 2 and 3 (Halbert); a 5% savings in energy use associated with that relift pumping is anticipated (Halbert). Inasmuch as this estimated savings is presumed to be associated with the total 8.92 miles of currently concrete-lined canal segments proposed to be either impervious-lined or replaced with pipeline, a proportionate amount (i.e., 3.26 miles out of 8.92 miles equals 36.5 percent) of the savings are attributed to this project component. Allowing for the five-year (1997-2001) average irrigation and M&I water use in the District of 67,401 ac-ft and using the 141,907.5 BTUs standard for pumping requirements, such reductions in relifting requirements of 492.6 ac-ft[10] should generate an additional 69,897,092 BTUs (20,486 kwh) of energy savings (**Table 5**). Assuming a $0.10 cost per kwh, the estimated annual relifting operations-related energy cost savings are $2,049 (**Table 5**).

---

9 More precise estimates are unavailable. The timely, economic development of new data is prohibitive within the project review timeline. The values assumed are deemed reasonable and prudent.

10 The noted reductions represent abatements in the amount of District pumping requirements, but not in diversions from the Rio Grande River. That is, this amount of water is still diverted and delivered, but the amount of pumping and associated energy requirements are reduced. Accordingly, the amount of water associated with energy savings in Table 5, 1,896.4 ac-ft, is 492.6 ac-ft greater than the 1,403.7 ac-ft noted for water savings.

Operating and Maintenance. It is estimated that annual expenditures for the O&M of the currently concrete-lined canal segments are $1,600 per mile (Blair). Thus, across the total 3.26 miles of currently concrete-lined delivery canals proposed for impervious-lining, a reduction of $5,215 O&M is anticipated (**Table 5**).

Reclaimed Property. No real property will be reclaimed in association with this project component (**Table 5**). Consequently, there is no realizable cash income to claim as a credit against the costs of this project component.

Component #3 -- 24" Pipelines Replacing Delivery Canals

Summary data for the third component of the District's proposed project, 24" pipelines replacing currently concrete-lined delivery canals, are presented in **Table 7.** Discussion of that data follows.

Description

This project component consists of installing 24-inch pipelines in place of six delivery canal segments (i.e., Wyrick D, E, and F; Taylor A; and Citrus A and B) which are currently concrete lined and have significant seepage problems (**Table 6; Table 7**). Replacing these 5.66 miles of currently concrete-lined delivery canals with 24" pipelines is expected to:

a) eliminate seepage estimated at 215.33 ac-ft/mile (Fipps 2000) (**Table 7**);
b) allow for the removal of a lock system and eliminate the need for several pumping stations; and
c) provide several secondary benefits, including increased flows to individual farms due to increased head and/or greater number of farms could be irrigated simultaneously, reducing the travel time and expense of the canal operators.

Installation Period

It is anticipated that it will take one year after purchase and project component initiation for the pipelines to be installed and their use to be fully implemented (**Table 7**). No losses of operations or otherwise adverse impacts are anticipated during the installation period since this will occur in the off-season.

Productive Period

A useful life of 49 years[11] for the 24" pipelines is expected and assumed in the baseline analysis (**Table 7**). A shorter-useful life is possible with the advent of new, more effective

---

11 Actually, the estimated useful life is 50 years instead of 49 years. RGIDECON© was developed to consider up to a maximum 50-year planning horizon, with the perspectives that projections beyond that length of time are largely discounted and also highly speculative. Allowing for the one-year installation period on the front end reduces to 49 years the time remaining for productive use of the asset during the 50-year planning period allowed within RGIDECON©.

technology. The 49-year estimate is reasonable and consistent, however, with prior observations in other locales (Blair). Sensitivity analyses are utilized to examine the effects of this assumption. The first year of the productive period is assumed to occur during year 2 of the 50-year planning period.

Costs

Two principal types of costs are of consequence when evaluating this proposed investment: the initial capital outlay and recurring operating and maintenance expenses. Assumptions related to each type of expenditure are presented below.

Initial. Based on discussions with Bureau of Reclamation management, expenses associated with design, engineering, and other preliminary development of this project component's proposal are ignored in the economic analysis prepared for the planning report. Such costs are to be incorporated, however, into the materials associated with the final design phase of this project component.

Capital investment costs during the installation stage of this project component total $1,106,080 in 2002 nominal dollars (**Table 7**) (Blair). This amount is related to purchase and installation of the six 24-inch pipeline segments totaling 5.66 miles in length (**Table 6**) (Blair). The cost estimate and total summed length of the six segments translate into an estimated cost of $195,387 per mile. Sensitivity analyses on the total amount of all capital expenditures are utilized to examine the effects of this assumption. All such expenditures are assumed to occur on day one of this project component's inception, avoiding the need to account for inflation in the cost estimates.

Recurring. O&M expenditures associated with the installed 24" pipelines are expected to be of a different magnitude than those presently occurring for the concrete-lined delivery canals. Annual operating and maintenance (O&M) expenditures associated with the affected segments of the canal delivery system are anticipated to be $200 per mile of pipeline, or a total of $1,132 (**Table 7**). Any O&M requirements during the first two years following installation of the 24" pipelines are assumed to be covered by warranty (Blair).

Projected Savings

Water. Water savings are reductions in diversions from the Rio Grande River, i.e., how much less water will be used by the District as a result of this project component's installation and utilization? Estimates of such savings are comprised, in this case, of both off-farm and on-farm savings with regards to agricultural (i.e., irrigation) water use only; i.e., no savings related to M&I water use are anticipated.

Off-farm savings are those occurring in the District's canal delivery system as a result of fewer leaks after the targeted canal segments are replaced with pipelines. Historic ponding test studies in the District by Fipps (2000) documenting water losses on concrete-lined canal segments similar to the ones proposed for replacing with 24" pipelines, in comparable soil series, indicate annual losses are 215.33 ac-ft of water per mile of canal. It is assumed here such losses will translate into savings at a 100% rate if the canals are replaced with 24" pipelines, i.e., all 215.33 ac-ft per mile of present losses will be saved. Fipps' estimates are admittedly applicable to the canal systems in their present state; additional deterioration and increased water losses and associated increases in O&M expenses should be expected as the respective segments age (Halbert; Carpenter). While mathematical representation of alternative time paths of such phenomena could be developed, the analysis is conservatively constrained to assuming a constant 215.33 ac-ft of annual water savings per mile of currently concrete-lined canal that is replaced with 24" pipelines (Blair).

The expected reductions in Rio Grande River diversions affiliated with off-farm water use are thus conservatively estimated at 215.33 acre-ft per mile for the 5.66 of currently concrete-lined delivery canals proposed to be replaced with 24" pipelines (**Table 6**). Such annual water savings total 1,219.0 ac-ft of water (**Table 7**). Sensitivity analyses are utilized to examine the effects of the 215.33 ac-ft per mile assumption.

Additional on-farm savings are expected in association with irrigation water use as a result of increased head at farm diversion points, allowing for faster irrigation of fields and resulting lower levels of percolation losses (Lewis and Milne). Similar to the assumption made for the impervious-lining of delivery canals component, on-farm savings are assumed here to equal off-farm savings (Blair). The annual amount of such on-farm savings in the base analysis is thus 1,219.0 ac-ft (**Table 7**). As with the other estimated water savings, these savings are held constant each year of the pipelines' productive period to provide for a conservative analysis. The on-farm savings estimates are directly linked to the assumed off-farm savings value, allowing for direct variance during the sensitivity analyses of savings per mile of pipeline. Combining off- and on-farm water savings results in 2,438.0 ac-ft per year.

<u>Energy</u>. Energy savings <u>may</u> occur as a result of less water being pumped at the Rio Grande River diversion site and also because of lower relift pumping requirements at one or more points throughout the canal delivery system. The amount of such energy savings and the associated monetary savings are detailed below.

Factors constituting energy savings associated with lessened diversion pumping are twofold: (a) less energy used for pumping and (b) the cost (value) of such energy. Recent historic records for the District are presented in **Table 4.** On average, 141,907.5 BTUs were used to pump each ac-ft of water used in the District during 2001. This value, in conjunction with the anticipated annual irrigation water savings off-farm totaling 1,219.0 ac-ft, infers anticipated annual irrigation energy savings of 172,982,401 BTUs (50,698 kwh) (**Table 7**). Assuming a $0.10 cost per kwh, the estimated annual irrigation energy cost savings are $5,070 in 2002 dollars (**Table 7**). Similar savings are anticipated for the assumed on-farm reductions in water use. Sensitivity analyses are utilized to examine the effects of the assumptions for both the amount of energy used per ac-ft of water pumped and the cost per unit of energy.

It is anticipated that the District's relift pumping operations for 40% of the total water use will be affected by project components #s 2 and 3 (Halbert); a 5% savings in energy use associated with that relift pumping is anticipated (Halbert). Inasmuch as this estimated savings is presumed to be associated with the total 8.92 miles of currently concrete-lined canal segments proposed to be either impervious-lined or replaced with 24" pipelines, a proportionate amount (i.e., 5.66 miles out of 8.92 miles equals 63.5 percent) of the savings are attributed to this project component. Allowing for the five-year (1997-2001) average irrigation and M&I water use in the District of 67,401 ac-ft and using the 141,907.5 BTUs standard for pumping requirements, such reductions in relifting requirements of 855.5 ac-ft[12] should generate an additional 121,395,938 BTUs (35,579 kwh) of energy savings (**Table 7**). Assuming a $0.10 cost per kwh, the estimated annual relifting operations-related energy cost savings are $3,075 (**Table 7**).

Operating and Maintenance. It is estimated that annual expenditures for the O&M of the currently concrete-lined canal segments are $1,600 per mile (Blair). Thus, across the total 5.66 miles of currently concrete-lined delivery canals proposed for replacing with 24" pipelines, a reduction of $13,845 O&M is anticipated (**Table 7**).

Reclaimed Property. No real property will be reclaimed in association with this project component (**Table 7**). Consequently, there is no realizable cash income to claim as a credit against the costs of this project component.

Component #4 -- On-Farm Delivery-Site Meters

Summary data for the fourth component of the District's proposed project, on-farm delivery-site meters, are presented in **Table 8.** Discussion of that data follows.

Description

This project component consists of installing 400 meters at farm irrigation delivery-site locations throughout the District delivery system (**Table 8**) (Blair). The meter devices will be permanent installations and data will be recorded by either infrared, active radio frequency, passive radio frequency, and/or bar code readers (Blair). The installation of permanent meters will be more stable and require less maintenance than portable meters.

The information generated by the meters will provide flow data useful in monitoring water usage and flows as well as for pricing water use to irrigators. The resulting improved management information will facilitate more efficient water delivery within the District's delivery system and also by farmers in their irrigation practices. Associated energy savings also will be realized with the reduced pumping requirements.

Installation Period

It is anticipated that it will take one year after purchase and project component initiation for the on-farm delivery-site meters to be installed and their use to be fully implemented (**Table 8**).

---

12 Similar to the effects of the impervious-lining of canals, these reductions in relift pumping due to the installation of pipelines save energy, but not water; i.e., the 855.5 ac-ft of water are still diverted and delivered to water users with the District. Accordingly, the amount of water associated with energy savings in Table 7, 3,293.1 ac-ft, is 855.5 ac-ft greater than the 2,438.0 ac-ft noted for water savings.

No losses of operations or otherwise adverse impacts are anticipated during the installation period since this will occur in the off-season.

Productive Period

A useful life of 10 years for the on-farm delivery-site meters is expected and assumed in the baseline analysis (**Table 8**). A shorter-useful life is possible with the advent of new, more effective technology. The 10-year estimate is reasonable and consistent, however, with prior observations in other locales (Blair). Sensitivity analyses are utilized to examine the effects of this assumption. The first year of the productive period is assumed to occur during year 2 of the 11-year planning period.

Costs

Two principal types of costs are of consequence when evaluating this proposed investment: the initial capital outlay and recurring operating and maintenance expenses. Assumptions related to each type of expenditure are presented below.

Initial. Based on discussions with Bureau of Reclamation management, expenses associated with design, engineering, and other preliminary development of this project component's proposal are ignored in the economic analysis prepared for the planning report. Such costs are to be incorporated, however, into the materials associated with the final design phase of this project component.

Capital investment costs during the installation stage of this project component total $649,816 in 2002 nominal dollars (**Table 8**). The total amount is related to purchase and installation of the on-farm delivery-site meters (Blair). Sensitivity analyses on the total amount of all capital expenditures are utilized to examine the effects of this assumption. All such expenditures are assumed to occur on day one of this project component's inception, avoiding the need to account for inflation in the cost estimates.

Recurring. Annual increases in operating and maintenance (O&M) expenditures are expected to total $114,675 in 2002 nominal dollars (**Table 8**) (Blair). Such expenses will commence during year two of the planning horizon and be indexed to account for expected inflation through the end of each year of the productive period.

Projected Savings

Water. Water savings of interest are reductions in diversions from the Rio Grande River, i.e., how much less water will be used by the District as a result of this project component's purchase, installation, and utilization? Estimates of such savings are comprised, in this case, of only on-farm savings with regards to agricultural (i.e., irrigation) water use, i.e., there are no off-farm savings anticipated directly attributable to the on-farm delivery-site meters with respect to either agricultural or M&I water.

The noted on-farm savings are expected to occur as a result of volumetric measuring and pricing of water to agricultural irrigators. Knowledge of the amount of water being used and the possibility of account credits for reduced water use potentially provide substantial incentives to agricultural irrigators. Similarly, irrigation cost savings forthcoming from volumetric pricing offer additional incentives for reduced water use by farmers.

Expected reductions in Rio Grande River diversions affiliated with on-farm water use are estimated at being equivalent to what occurred when 50% of the District's current agricultural water use began to be volumetrically measured (Blair). That is, it is expected that Rio Grande River diversions will be reduced by 27 percent on the remaining one-half of agricultural water that will be affected by installation of the on-farm delivery-site meters (Blair; Halbert). The five-year (1997-2001) average irrigation water use in the District is 45,619 ac-ft (**Table 2**). Twenty-seven percent of one-half of that quantity of water is equivalent to 6,158.5 ac-ft of annual savings (**Table 8**).

Although it would be reasonable to assume annual savings would increase through this project component's duration (at least up to some maximum higher level) as a result of increasing management knowledge and abilities related to the use of the enhanced water flow and usage information, the level of savings is held constant each year to provide for a conservative analysis. Sensitivity analyses are utilized to examine the effects of this assumption.

Energy. Energy savings may occur as a result of less water being pumped at the Rio Grande River diversion site and also because of lower relift pumping requirements at one or more points throughout the canal delivery system. The amount of such energy savings and the associated monetary savings are detailed below.

Factors constituting energy savings associated with lessened diversion pumping are twofold: (a) amount of energy used for pumping and (b) the cost (value) of such energy. Recent energy records for the District are presented in **Table 4.** On average, 141,907.5 BTUs were used to pump each ac-ft of water used in the District during 2001 (Halbert). This value, in conjunction with the anticipated annual irrigation water savings on-farm totaling 6,158.5 ac-ft, infers anticipated annual irrigation energy savings of 873,942,808 BTUs (256,138 kwh) (**Table 8**). Assuming a $0.10 cost per kwh, the estimated annual irrigation energy cost savings are $25,614 (**Table 8**). Sensitivity analyses are utilized to examine the effects of the assumptions for both the amount of energy used per ac-ft of water pumped and the cost per unit of energy.

No changes in relift pumping operations are anticipated in association with this project component. Thus, there are no additional energy savings to be tallied.

Operating and Maintenance. No reductions in O&M expenditures are anticipated for this project component (**Table 8**). Consequently, there is no claim in this respect as a credit against the costs of this project component.

Reclaimed Property. No real property will be reclaimed in association with this project component (**Table 8**). Consequently, there is no realizable cash income to claim as a credit against the costs of this project component.

Abbreviated Discussion of Methodology[13]

Texas Agricultural Experiment Station and Texas Cooperative Extension economists have developed an economic spreadsheet model, RGIDECON© (Rio Grande Irrigation District Economics), to facilitate economic and conservation analyses of the capital renovation projects proposed by South Texas irrigation districts. The spreadsheet's calculations are attuned to economic and financial principles consistent with capital budgeting procedures for evaluating projects of different economic lives, thereby "leveling the playing field" and allowing "apples to apples" comparisons across projects. As a result, RGIDECON© also is capable of providing valuable information for implementing a method of prioritization of projects in the event of funding limitations.

The results of a RGIDECON© analysis can be used in comparisons to exogenously-specified economic values of water to easily provide for implications of a cost-benefit analysis. Methodology similar to that presented for water savings also is included in the spreadsheet for appraising the economic costs associated with energy savings (both on a BTU and kwh basis). That is, there are energy savings both from pumping less water forthcoming from reducing leaks and from improving the efficiency of pumping plants.

RGIDECON©'s economic and energy savings analyses provide an estimate of the economic costs per ac-ft of water savings and per BTU (kwh) of energy savings associated with each proposed capital improvement activity (i.e., an individual component). An aggregate assessment is also provided for those proposed projects consisting of two or more activities (i.e., components). Lastly, the RGIDECON© model has been designed to accommodate "what if" analyses for Districts interested in evaluating additional, non-Act authorized capital improvement investments in their water delivery infrastructure.

Public Law 106-576 legislation requires a variation of economic analyses in which the initial construction costs and annual economic savings are used independently in assessing the potential of capital renovations proposed by irrigation districts (Bureau of Reclamation). In addition, all calculations are performed on a nominal rather than real basis (Hamilton).

Detailed results for the economic and financial analyses following the methodology presented in Rister et al. (2002) appear in subsequent sections of the main body of this report. Results for the legislative criteria appear in Appendices A and B.

---

13 The publication, "Economic Methodology for South Texas Irrigation Projects – RGIDECON©," Texas Water Resources Institute TR-203 (Rister et al. 2002), provides a more extensive documentation of the methodology employed in conducting the analyses presented in this report. Excerpts from that publication are included in this section; several of the authors of this report are co-authors of TR-203. The methodology documented in Rister et al. 2002 was endorsed in July, 2002, as expressed by Larry Walkoviak, Area Manager of the Oklahoma-Texas Office of the Bureau of Reclamation, "The results of the model will fully satisfy the economic and conservation analyses required by the Act and it may be used by any irrigation district or other entity seeking to qualify a project for authorization and/or construction funding under P.L. 106-576."

Assumed Values for Critical Parameters

This section of the report presents the values assumed for several parameters which are considered critical in their effects on the overall analysis results. This discussion is isolated here to emphasize the importance of these parameters and to highlight the values used.[14]

Discount Rates and Compound Factors

The discount rate used for calculating net present values of the different cost streams represents a firm's required rate of return on capital (i.e., interest) or, as sometimes expressed, an opportunity cost on its capital. The discount rate is generally considered to contain three components: a risk-free component for time preference (i.e., social time value), a risk premium, and an inflation premium (Rister et al. 1999).

One estimate of such a discount rate from the District's perspectives would be the cost at which it can borrow money (Hamilton). Griffin notes, however, that because of the potential federal funding component of the project, it could be appropriate to ignore the risk component of the standard discount rate as that is the usual approach for federal projects. Hamilton notes that the Federal discount rate consists of two elements, time value of money and inflation, but that the rate is routinely used as a real rate, ignoring the inflationary component. After considering those views and interacting with Penson and Klinefelter, Texas A&M University agricultural economists specializing in financing, the 2002 Federal discount rate of 6.125% was adopted for use in discounting all financial streams.

Recognition of the potential for uneven annual flows of water and energy savings associated with different project components and different projects encourages normalizing such flows through calculation of the net present value of water and energy savings. In the absence of complete cost-benefit analysis and the associated valuation of water and energy savings, it is acknowledged that there is no inflationary influence to be accounted for during the discounting process (Klinefelter), i.e., only the time value (t) should be recognized in the discounting process. Accordingly, a lower rate than the 6.125% 2002 Federal discount rate is desired. Consultations with Griffin and Klinefelter contributed to adoption of the 4% rate used by Griffin and Chowdhury for the social time value in these analyses.

As presented in Rister et al. (2002), use of an overall discount rate of 6.125% in conjunction with a 4% social time value and the assumption of a 0% risk premium infers a 2.043269% annual inflation rate. Such an inferred rate is consistent with recent and expected rates of nominal price increases for irrigation construction, O&M, and energy costs (Rister et al. 2002). Thus, a 2.043269% rate is used to compound 2002 nominal dollar cost estimates forward for years in the planning period beyond 2002. Rationale for assuming this rate is based both on the mathematical

---

14 As was the case in the previous "Abbreviated Discussion of Methodology" section, some of the text in this section is a capsulated version of what is presented in Rister et al. (2002).

relationship presented above and analyses of several pertinent price index series and discussions with selected professionals.[15]

Pre-Project Annual Water Use by the District

Water availability and use in the District has varied considerably in recent years as a result of water shortages in the Rio Grande Basin. **Table 2** contains the District's historic water use among agricultural irrigation and M&I along with an indication of the total use for each of the five most recent years (1997-2001). Rather than isolate one particular year as the baseline on which to base estimates of future water savings, Bureau of Reclamation, Texas Water Development Board, Texas Agricultural Experiment Station, and Texas Cooperative Service representatives agreed during the summer of 2002 to use the average levels of use during this five-year period as a proxy for the baseline (Clark et al. 2002a). At a subsequent meeting in July (Clark et al. 2002b), consideration was directed to recognizing, when appropriate, how allocation restrictions in recent years may have adversely affected such a five-year average to the extent that the values do not adequately represent potential irrigated acreage in future years during the project's planning period. Where an irrigation district has been impacted by allocation restriction(s), a more-lengthy time series of water use is to be used to quantify representative water use.

As discussed in more detail earlier in this report, this District's agricultural irrigation use has averaged 45,619 ac-ft during the designated 5-year period. M&I use is more consistent, averaging 21,782 ac-ft. The average total water use within the District during 1997-2001 is 67,401 ac-ft. These values are perceived as appropriate for gauging future use during this project's planning period (Halbert).

Value of Water Savings per Acre-Foot of Water

The analyses reported in this report focus on identifying the costs per ac-ft of water saved and per BTU and kwh of energy saved. The value of water is ignored in the analysis, essentially stopping short of a complete benefit-cost analysis.[16] The results of this analysis can be used, however, in comparisons to exogenously-specified economic values of water to easily provide for implications of a cost-benefit analysis.

---

[15] Admittedly, excessive precision of accuracy is implied in this assumed value for the rate of annual cost increases. Such accuracy of future projections is not claimed, however, but rather that this precise number is that which satisfies the multiplicative elements of the overall discount rate calculation discussed in Rister et al. (2002), assuming the noted values for risk and time value.

[16] RGIDECON© includes opportunities for the value of agricultural irrigation water and the incremental differential value associated with M&I water to be specified, thereby facilitating comprehensive benefit-cost analyses. For the purposes of this study, however, such values are set at $0.00, thereby meeting the assessment requirements specified in the Public Law 106-576 legislation.

Energy Usage per Acre-Foot of Water

Essential elements of this analysis include calculating the cost of energy savings and also recognizing the value of such savings as a reduction in O&M expenditures when evaluating the cost of water savings associated with the respective project components.[17] Historic average energy usage levels per ac-ft of water pumped by the District for calendar year 2001 are used to represent the amount of energy that will be saved when less water is pumped due to reductions in leaks and other source(s) of water use reductions forthcoming from the proposed project component(s). As previously presented, recent electrical-use records for the District are presented in **Table 4.** On average, 141,907.5 BTUs were used to pump each ac-ft of water used in the District during 2001 (Halbert). Thus, it is anticipated that this amount of energy (i.e., 141,907.5 BTUs) will be saved when diversions from the Rio Grande River are lessened by one ac-ft. Other factors of significance are the assumption of there being 3,412 BTUs per kwh (Infoplease.com), allowing for translation of the energy savings information into an alternative form for presentation to readers of this report.

Value of Energy Savings per BTU/kwh

Similar to the manner in which average values are used to represent physical energy unit savings associated with lessened diversions from the Rio Grande River, average costs of energy are used to transform the expected energy savings into an economic value. Discussions with Halbert indicate recent costs of electrical power for the District have ranged from $0.08 to $0.125 per kwh. A $0.10 cost level was assumed in the analyses reported herein as an average, mid-range cost. Sensitivity analyses are utilized to examine the effects of this assumption.

Economic and Financial Evaluation Results by Component

The economic and financial analyses results forthcoming from an evaluation of the afore-mentioned data using RGIDECON© (Rister et al. 2002) are presented in this section for individual project components. Results aggregated across the four project components (canal meters and telemetry equipment, impervious-lining of delivery canals, 24" pipelines replacing delivery canals, and on-farm delivery-site meters) are presented in a subsequent section.

Component #1 – Canal Meters and Telemetry Equipment

The first component evaluated is the installation of canal meters and telemetry equipment at pump sites and throughout intermediate canal division points in the District's canal delivery system. Results of the analysis of that component follow (**Table 9**).

---

17 "There are interests in identifying mutually-exclusive estimates of the costs per unit of (a) water saved and (b) energy saved for the respective projects and their component(s). 'Mutually-exclusive' refers to each respective estimate being calculated independent of the other. The measures are not intended to be additive ... – they are single measures, representing different perspectives of the proposed projects and their component(s)." (Rister et al. 2002)

Quantities of Water and Energy Savings

Critical values in the analyses are the quantities of water and energy anticipated being saved during the 15-year productive life of the canal meters and telemetry equipment. On a nominal (i.e., non-discounted) basis, 20,528 ac-ft of irrigation water are projected to be saved and another 9,802 ac-ft of M&I water savings are also estimated using the values presented earlier. Thus, the total nominal water savings anticipated are 30,330 ac-ft across the 15-year productive life of this component (**Table 9**). Using the 4% discount rate previously discussed, those nominal savings translate into 14,631 ac-ft of real irrigation savings and 6,986 ac-ft of real M&I water savings, representing a total real water savings of 21,617 ac-ft (**Table 9**).

On a nominal (i.e., non-discounted) basis, 2,913,142,694 BTUs of energy savings are projected to be saved in association with the forecast irrigation water savings. Another 1,390,950,475 BTUs of nominal energy saving are expected as a result of the potential M&I water savings. Thus, the total nominal energy savings anticipated are 4,304,093,170 BTUs (1,261,457 kwh) over the 15-year productive life of this component (**Table 9**). Using the 4% discount rate previously discussed, those nominal savings translate into 2,076,246,739 BTUs of real irrigation-related energy savings and 991,354,249 BTUs of real M&I-related energy savings, representing a total real savings of 3,067,600,987 BTUs (899,062 kwh) (**Table 9**).

Cost of Water Saved

One principal gauge of a proposed project component's merit is the estimated cost per ac-ft of water saved as a result of this project component's inception, purchase, installation, and implementation. Both deterministic results based on the expected values for all parameters integrated into the RGIDECON© assessments and sets of sensitivity analyses for several pairs of the data parameters are presented below for component #1, canal meters and telemetry equipment.

NPV of Net Cost Stream. Accounting for all capital purchase and installation construction costs, changes in O&M expenditures, and credits for energy savings, the nominal total cost of the 16-year planning period for the canal meters and telemetry equipment component of the District's project is $2,677,086 (**Table 9**). Using the previously-identified discount rate of 6.125%, these nominal cost dollars translate into present-day, real costs of $1,893,594 (**Table 9**). This amount represents, across the total 16-year planning period, the total net costs, in 2002 dollars, of purchasing and installing the canal meters and telemetry equipment as well as payment of the net changes in O&M expenditures.

NPV of All Water Savings. As detailed above, the total nominal water savings anticipated are 30,330 ac-ft (**Table 9**). The corresponding total real water savings expressed in 2002 water quantities are 21,617 ac-ft, assuming the previously-identified discount rate of 4.00% (**Table 9**).

Cost per Acre-Foot of Water Saved. Combining the real net cost estimate of $1,893,594 and the real water savings projection of 21,617 ac-ft, the estimated cost of saving one ac-ft of water using the canal meters and telemetry equipment comprising this project component is $87.60 (**Table 9**). This value can be interpreted as the cost of leasing one ac-ft of water in year 2002. It is not the cost of purchasing the water right for one ac-ft. Following through with the economic and capital budgeting methodology presented in Rister et al. (2002) results, however, in this same cost measure (i.e., $87.60), representing the costs per year in present-day dollars of saving one ac-ft of water each year into perpetuity through a continual replacement series of the canal meters and telemetry equipment with all of the attributes previously indicated.

Sensitivity Results. The results presented above are predicated on numerous assumed values incorporated into the RGIDECON© analysis. Those assumed values and the logic for their assumed values are presented in prior sections. Here, attention is directed toward varying some of those values across a plausible range of possibilities, thereby seeking to identify the stability/instability of the estimated cost measure (e.g., $ costs per ac-ft of water saved) in response to changes in certain key parameters. The two-way Data Table feature of Excel (Walkenbach) is utilized to accomplish these sensitivity analyses whereby two parameters are varied and all others remain constant at the levels assumed for the baseline analysis.

The most critical assumption made in the baseline analysis is considered to be that pertaining to the amount of reduction in Rio Grande River diversions that will result from the purchase, installation, and implementation of the meters and telemetry equipment in the canal delivery system. Thus, the cost per ac-ft of water-saved sensitivity analyses consist of varying the water savings dimension across a range of 0.5 percent up to 10.0 percent (including the baseline 3.0 percent) of the District's historic five-year (1997-2001) average water-usage level paired with variances in three other fundamental factors: (a) expected useful life of the investment; (b) initial capital investment costs; and (c) value of BTU savings (i.e., cost of energy). Results for these three sets of sensitivity analyses are presented in **Tables 10, 11,** and **12**, respectively.

Table 10 reveals a range of $23.37 to $1,364.59 cost per ac-ft of savings around the baseline estimate of $87.60. These calculated values were derived by varying the percent reduction in Rio Grande River diversions arising from off-farm, in-delivery system water savings across a range of 0.50% to 10.0% about the expected 3.0% and by investigating a range of useful lives of the canal meters and telemetry equipment down from the expected 15 years to as short as only 5 years.[18] As should be expected, shorter-useful lives than the anticipated 15-year productive life resulted in higher cost estimates, lower off-farm water savings than the predicted 3% also increased cost estimates, and higher-than-expected water savings contributed to lower cost estimates.

Similarly, **Table 11** is a presentation of a range of cost estimates varying from $20.59 to $601.89 per ac-ft of savings around the baseline estimate of $87.60. These calculated values were derived by varying the percent reduction in Rio Grande River diversions arising from off-

18 Sensitivity analyses of the expected useful life parameter are limited in this report to lives shorter than the expected lives of the respective capital investment components. The data collection process of this investigation did not include identifying O&M costs and other relevant information beyond the expected useful life planning horizon for each component, thereby preventing evaluation of the effects of such extended productive lives.

farm, in-delivery system water savings across a range of 0.50% to 10.0% about the expected 3.0% and by considering variations in the cost of the capital investment in the canal meters and telemetry equipment varying from $200,000 less than the expected $757,538 up to $200,000 more than the expected amount. As should be expected, both lower-than-the-anticipated $757,538 capital costs and/or higher-than-expected water savings contributed to lower cost estimates while both higher investment costs and/or lower off-farm water savings than the predicted 3% increased the cost estimates.

The final set of sensitivity analyses conducted for the costs of water savings accounted for varying both the percent reduction in Rio Grande River diversions arising from off-farm, in-delivery system water savings and the cost of energy. **Table 12** is an illustration of the results of varying those parameters from as low as 0.50% up to 10.0% about the expected 3.0% off-farm water savings and across a range of $0.08 to $0.12 per kwh energy costs about the assumed $0.10 per kwh level. The resulting costs of water savings estimates ranged from a high of $547.21 per ac-ft down to a low of $22.54 per ac-ft. Both higher-than-anticipated water savings and higher-than-expected energy costs contributed to lower cost of water savings estimates while both lower-than-anticipated water savings and lower-than expected energy costs increased the cost of water savings estimates.

Cost of Energy Saved

Besides the estimated cost per ac-ft of water saved as a result of the canal meters and telemetry equipment's inception, purchase, installation, and implementation, another issue of interest is the cost of energy savings.[19] Reduced water diversions from the Rio Grande River will result as improved water management reduces over-deliveries (i.e., potential "spills") and minimizes "over-orders." These reduced diversions associated with the proposed canal meters and telemetry equipment capital renovation result in less water being pumped, translating into energy savings. Both deterministic results based on the expected values for all parameters integrated into the RGIDECON© assessments and sets of sensitivity analyses for several pairs of the data parameters are presented below for component #1, canal meters and telemetry equipment.

NPV of Net Cost Stream. Accounting for all capital purchase and installation construction costs, and changes in O&M expenditures, the nominal total cost of the 16-year planning period for the canal meters and telemetry equipment component of the District's project is $2,828,997 (**Table 9**). Using the previously-identified discount rate of 6.125%, these nominal cost dollars translate into a present-day, real cost of $1,983,501 (**Table 9**). This amount represents, across the total 16-year planning period, the total net costs, in 2002 dollars, of purchasing and installing the canal meters and telemetry equipment as well as payment of the net changes in O&M expenditures, ignoring the changes in energy costs and allowing no credits for the water savings.

---

19 As noted previously, cost of energy savings are calculated ignoring the costs of water savings calculations (Rister et al. 2002).

NPV of All Energy Savings. As detailed above, the total nominal energy savings anticipated are 4,304,093,170 BTUs (1,261,457 kwh) (**Table 9**). The corresponding total real energy savings expressed in 2002 energy quantities are 3,067,600,987 BTUs (899,062 kwh), assuming the previously-identified discount rate of 4.00% (**Table 9**).

Cost per BTU & kwh Saved. Combining the real net cost estimate of $1,983,501 and the real energy savings projection of 3,067,600,987 BTUs (899,062 kwh), the estimated cost of saving one BTU of energy using the canal meters and telemetry equipment technology comprising this project component is $0.0006466 ($2.206 per kwh) (**Table 9**). An interpretation of this value is that it is the cost of saving one BTU (kwh) of energy in year 2002. Following through with the economic and capital budgeting methodology presented in Rister et al. (2002) results, however, in this same cost measure (i.e., $0.0006466 per BTU or $2.206 per kwh), representing the costs per year in present-day dollars of saving one BTU (kwh) of energy into perpetuity through a continual replacement series of the canal meters and telemetry equipment with all of the attributes previously indicated.

Sensitivity Results. As with the cost of water-savings estimates, the results presented above for energy savings are predicated on numerous assumed values incorporated into the RGIDECON© analysis. Those assumed values and the logic for their assumed values are presented in prior sections. Here, attention is directed toward varying some of those values across a plausible range of possibilities, thereby seeking to identify the stability/instability of the estimated cost measure (i.e., $ costs per BTU (or kwh) saved) in response to changes in certain key parameters. The two-way Data Table feature of Excel (Walkenbach) again is utilized to accomplish these sensitivity analyses whereby two parameters are varied and all others remain constant at the levels assumed for the baseline analysis.

The most critical assumption made in the baseline analysis in this respect is considered to be that pertaining to the amount of energy savings that will result from the purchase, installation, and implementation of the meters and telemetry equipment in the canal-delivery system. Thus, the cost per BTU (or kwh) of energy-saved per ac-ft of water saved sensitivity analyses consists of varying the amount of energy savings across a range of 80.0 percent up to 150.0 percent of the baseline 141,908 BTUs (41.59 kwh) current average usage per ac-ft of water savings paired with variances in three other fundamental factors: (a) expected useful life of the investment; (b) initial capital investment costs; and (c) percent water savings of current off-farm use. Results on a BTU and kwh basis for these three sets of sensitivity analyses are presented in **Tables 13** and **14**, **15** and **16**, and **17** and **18**, respectively.

Tables 13 and **14** reveal a range of $0.0004311 to $0.0020186 cost per BTU (and $1.471 to $6.887 per kwh) of energy savings around the baseline estimate of $0.0006466 per BTU ($2.206 per kwh). These calculated values were derived by varying the amount of energy used per ac-ft of water savings across a range as low as 80.0% up to 150.0% of the expected 141,908 BTUs (41.59 kwh) current average usage per ac-ft of water savings and by investigating a range of useful lives of the capital investment in the canal meters and telemetry equipment down from the expected 15 years to as short as only 5 years. As should be expected, shorter-useful lives than the anticipated 15-year productive life resulted in higher cost estimates, lower energy savings than the predicted 100% of current average usage also increased cost estimates, and higher-than-expected energy savings contributed to lower cost estimates.

Similarly, **Tables 15** and **16** are a presentation of a range of cost estimates varying from $0.0003876 to $0.0008897 per BTU (and $1.322 to $3.036 per kwh) of energy savings around the baseline estimate of $0.0006466 per BTU ($2.206 per kwh). These calculated values were derived by varying the amount of energy used per ac-ft of water savings across a range as low as 80.0% up to 150.0% of the expected 141,908 BTUs (41.59 kwh) current average usage per ac-ft of water savings and by considering variations in the cost of the capital investment in the canal meters and telemetry equipment varying from $200,000 less than the expected $757,538 up to $200,000 more than the expected amount. As should be expected, both lower-than-the-anticipated $757,538 capital costs and/or higher-than-expected energy savings contributed to lower cost estimates while both higher investment costs and/or lower energy savings than the predicted 141,908 BTUs (41.59 kwh) increased the cost estimates.

The final set of sensitivity analyses conducted for the costs of energy savings accounted for varying both the amount of energy used per ac-ft of water savings and the percent reduction in Rio Grande River diversions arising from off-farm, in-delivery system water savings. **Tables 17** and **18** are illustrations of the results of varying those parameters from as low as 80.0% up to 150.0% of the expected 141,908 BTUs (41.59 kwh) current average usage per ac-ft of water savings and from as low as 0.50% up to 10.0% about the expected 3.0% off-farm water savings. The resulting cost of energy savings estimates ranged from a high of $0.0048495 per BTU ($16.546 per kwh) down to a low of $0.0001293 per BTU ($0.441 per kwh). The lower cost estimates are associated with high energy usage per ac-ft of water savings and high off-farm water savings – the two factors combined contribute to substantial energy cost savings. The opposite effect is experienced with low energy usage per ac-ft of water savings and low off-farm water savings, i.e., higher costs estimates are calculated for these circumstances.

Component #2 -- Impervious-Lining of Delivery Canals

The second component evaluated is the impervious-lining of 3.66 miles of what are currently concrete-lined delivery canals located across four different sites in the District's canal delivery system. Results of the analysis of that component follow (**Table 19**).

<u>Quantities of Water and Energy Savings</u>

Critical values in the analyses are the quantities of water and energy anticipated being saved during the 20-year productive life of the impervious-lined delivery canals. On a nominal (i.e., non-discounted) basis, 29,478 ac-ft of irrigation water are projected to be saved; no M&I water savings are expected as a result of this project component. Thus, the total nominal water savings anticipated are 29,478 ac-ft over the 20-year productive life of this component (**Table 19**). Using the 4% discount rate previously discussed, those nominal savings translate into 18,343 ac-ft of real irrigation savings and 0.0 ac-ft of real M&I water savings, representing a total real water savings of 18,343 ac-ft (**Table 19**).

On a nominal (i.e., non-discounted) basis, 5,651,015,214 BTUs (1,656,218 kwh) of energy savings are projected to be saved in association with the forecast irrigation water savings (**Table 19**). Since there are no M&I-related energy savings, these values represent the total energy savings for this project component. Using the 4% discount rate previously discussed, those nominal savings translate into 3,516,444,182 BTUs (1,030,611 kwh) of real irrigation-related energy savings (**Table 19**).

<u>Cost of Water Saved</u>

One principal gauge of a proposed project component's merit is the estimated cost per ac-ft of water saved as a result of the project component's inception, purchase, installation, and implementation. Both deterministic results based on the expected values for all parameters integrated into the RGIDECON© assessments and sets of sensitivity analyses for several pairs of the data parameters are presented below for component #2, impervious-lining of delivery canals.

<u>NPV of Net Cost Stream</u>. Accounting for all capital purchase and installation construction costs, changes in O&M expenditures, and credits for energy savings, the nominal total cost of the 21-year planning period for the impervious-lined delivery canals component of the District's project is $375,624 (**Table 19**). Using the previously-identified discount rate of 6.125%, these nominal cost dollars translate into present-day, real costs of $535,049 (**Table 19**). This amount represents, across the total 21-year planning period, the total net costs, in 2002 dollars, of purchasing and installing the impervious-lined delivery canals as well as payment of the net changes in O&M expenditures. Note that the real-value amount of costs is greater than the nominal-value amount. This result occurs because in the nominal-value amount, the savings accruing from reduced energy use in the lengthy planning period are sufficient to offset a substantial amount of the initial investment costs. In the case of the real-value amount, however, the savings occurring during the latter years of the planning period are discounted significantly and thus do not offset as much of the initial investment costs.

<u>NPV of All Water Savings</u>. As detailed above, the total nominal water savings anticipated are 29,478 ac-ft (**Table 19**). The corresponding total real water savings expressed in 2002 water quantities are 18,343 ac-ft, assuming the previously-identified discount rate of 4.00% (**Table 19**).

<u>Cost per Acre-Foot of Water Saved</u>. Combining the real net cost estimate of $535,049 and the real water savings projection of 18,343 ac-ft, the estimated cost of saving one ac-ft of water using the impervious-lined delivery canals technology comprising this project component is $29.17 (**Table 19**). This value can be interpreted as the cost of leasing one ac-ft of water in year 2002. It is not the cost of purchasing the water right of one ac-ft. Following through with the economic and capital budgeting methodology presented in Rister et al. (2002) results, however, in this same cost measure (i.e., $29.17), representing the <u>costs per year</u> in present-day dollars of <u>saving one ac-ft of water each year</u> into perpetuity through a continual replacement series of the impervious-lined delivery canals with all of the attributes previously indicated.

<u>Sensitivity Results</u>. The results presented above are predicated on numerous assumed values incorporated into the RGIDECON© analysis. Those assumed values and the logic for their assumed values are presented in prior sections. Here, attention is directed toward varying some of those values across a plausible range of possibilities, thereby seeking to identify the stability/instability of the estimated cost measure (i.e., $ costs per ac-ft of water saved) in response to changes in certain key parameters. The two-way Data Table feature of Excel (Walkenbach) is utilized to accomplish these sensitivity analyses whereby two parameters are varied and all others remain constant at the levels assumed for the baseline analysis.

The most critical assumption made in the baseline analysis is considered to be that pertaining to the amount of reduction in Rio Grande River diversions that will result from the purchase, installation, and implementation of the impervious-lined delivery canals in the canal delivery system. Thus, the cost per ac-ft of water-saved sensitivity analyses consist of varying the off-farm water-savings dimension[20] of that factor across a range of 50 to 300 ac-ft (including the baseline 215.33 ac-ft) per mile of impervious-lined canal paired with variances in three other fundamental factors: (a) expected useful life of the investment; (b) initial capital investment costs; and (c) value of BTU savings (i.e., cost of energy). Results for these three sets of sensitivity analyses are presented in **Tables 20, 21,** and **22**, respectively.

Table 20 reveals a range of $19.72 to $426.82 cost per ac-ft of savings around the baseline estimate of $29.17. These calculated values were derived by varying the reduction in Rio Grande River diversions arising from off-farm water savings per mile of impervious-lined canal from as low as 50 ac-ft up to 300 ac-ft about the expected 215.33 ac-ft and by investigating a range of useful lives of the impervious-lined delivery canals down from the expected 20 years to as short as only 5 years. As should be expected, shorter-useful lives than the anticipated 20-year productive life resulted in higher cost estimates, lower off-farm water savings than the predicted 215.33 ac-ft per mile also increased cost estimates, and higher-than-expected water savings contributed to lower cost estimates.

Similarly, **Table 21** is a presentation of a range of cost estimates varying from $11.90 to $186.77 per ac-ft of savings around the baseline estimate of $29.17. These calculated values were derived by varying the reduction in Rio Grande River diversions arising from off-farm water savings per mile of impervious-lined canal from as low as 50 ac-ft up to 300 ac-ft about the expected 215.33 ac-ft and by considering variations in the cost of the capital investment in the impervious-lined delivery canals varying from $200,000 less than the expected $696,565 up to $200,000 more than the expected amount. As should be expected, both lower-than-the-anticipated $696,565 capital costs and/or higher-than-expected water savings contributed to lower cost estimates while both higher investment costs and/or lower off-farm water savings than the predicted 3% increased the cost estimates.

The final set of sensitivity analyses conducted for the costs of water savings accounted for varying both the reduction in Rio Grande River diversions arising from investment in impervious-lined delivery canals and the cost of energy. **Table 22** is an illustration of the results

---

20 Per discussions with Blair and Halbert and as previously noted, on-farm water savings are linked to off-farm water savings within RGIDECON©'s assessment of this component of the proposed project. Thus, as the off-farm water savings associated with the impervious-lining of delivery canals are varied in the sensitivity analyses, the on-farm savings also vary.

of varying those parameters from as low as 50 ac-ft up to 300 ac-ft about the expected 215.33 ac-ft per mile off-farm water savings and across a range of $0.08 to $0.12 per kwh energy costs about the assumed $0.10 per kwh level. The resulting costs of water savings estimates ranged from a high of $141.97 per ac-ft down to a low of $18.65 per ac-ft. The lower cost results are associated with high water savings and high energy costs. In instances when this happens, the two factors combined contribute to substantial energy cost savings which substantially offset both the initial capital costs of the impervious-lined delivery canals plus the anticipated changes in O&M expenses. The opposite effect is experienced with low energy usage per ac-ft of water savings and low water savings, i.e., higher costs estimates are calculated for these circumstances.

Cost of Energy Saved

Besides the estimated cost per ac-ft of water saved as a result of the impervious-lined delivery canals' inception, purchase, installation, and implementation, another issue of interest is the cost of energy savings. Reduced water diversions from the Rio Grande River will result as improved water management minimizes over-deliveries and increases head at on-farm delivery sites (thereby reducing on-farm water use). These reduced diversions and reduced use associated with the proposed impervious-lining of delivery canals capital renovation result in less water being pumped, translating into energy savings. Additional energy savings are also projected for this component in association with reduced relift pumping. Both deterministic results based on the expected values for all parameters integrated into the RGIDECON© assessments and sets of sensitivity analyses for several pairs of the data parameters are presented below for component #2, impervious-lining of delivery canals.

NPV of Net Cost Stream. Accounting for all capital purchase and installation construction costs, and changes in O&M expenditures, the nominal total cost of the 21-year planning period for the impervious-lined delivery canals component of the District's project is $588,332 (**Table 19**). Using the previously-identified discount rate of 6.125%, these nominal cost dollars translate into a present-day, real cost of $641,438 (**Table 19**). This amount represents, across the total 21-year planning period, the total net costs, in 2002 dollars, of purchasing and installing the impervious-lined delivery canals as well as payment of the net changes in O&M expenditures, ignoring the changes in energy costs and allowing no credits for the water savings.

NPV of All Energy Savings. As detailed above, the total nominal energy savings anticipated are 5,651,015,214 BTUs (1,656,218 kwh) over the 20-year productive life of this component (**Table 19**). The corresponding total real energy savings expressed in 2002 energy quantities are 3,516,444,182 BTUs (1,030,611 kwh), assuming the previously-identified discount rate of 4.00% (**Table 19**).

Cost per BTU & kwh Saved. Combining the real net cost estimate of $641,438 and the real energy savings projection of 3,516,444,182 BTUs (1,030,611 kwh), the estimated cost of saving one BTU of energy using the impervious-lined delivery canals technology comprising this project component is $0.0001824 ($0.622 per kwh) (**Table 19**). An interpretation of this value is that it is the cost of saving one BTU (kwh) of energy in year 2002. Following through with the economic and capital budgeting methodology presented in Rister et al. (2002) results, however, in this same cost measure ($0.0001824 per BTU or $0.622 per kwh), representing the costs per year in present-day dollars of saving one BTU (kwh) of energy into perpetuity through a continual replacement series of the impervious-lined delivery canals with all of the attributes previously indicated.

Sensitivity Results. As with the cost of water-savings estimates, the results presented above for energy savings are predicated on numerous assumed values incorporated into the RGIDECON© analysis. Those assumed values and the logic for their assumed values are presented in prior sections. Here, attention is directed toward varying some of those values across a plausible range of possibilities, thereby seeking to identify the stability/instability of the estimated cost measure (i.e., $ costs per BTU (or kwh) saved) in response to changes in certain key parameters. The two-way Data Table feature of Excel (Walkenbach) again is utilized to accomplish these sensitivity analyses whereby two parameters are varied and all others remain constant at the levels assumed for the baseline analysis.

The most critical assumption made in the baseline analysis in this respect is considered to be that pertaining to the amount of energy savings that will result from the purchase, installation, and implementation of the impervious-lined delivery canals in the canal delivery system. Thus, the cost per BTU (or kwh) of energy-saved sensitivity analyses consists of varying the amount of energy savings across a range of 80.0 percent up to 150.0 percent of the baseline 141,908 BTUs (41.59 kwh) current average usage per ac-ft of water savings paired with variances in three other fundamental factors: (a) expected useful life of the investment; (b) initial capital investment costs; and (c) off-farm water savings per mile of impervious-lined canal. Results on a BTU and kwh basis for these three sets of sensitivity analyses are presented in **Tables 23** and **24, 25** and **26**, and **27** and **28**, respectively.

Tables 23 and **24** reveal a range of $0.0001216 to $0.0006961 cost per BTU (and $0.415 to $2.375 per kwh) of energy savings around the baseline estimate of $0.0001824 per BTU ($0.622 per kwh). These calculated values were derived by varying the amount of energy used per ac-ft of water savings across a range as low as 80.0% up to 150.0% of the expected 141,908 BTUs (41.59 kwh) current average usage per ac-ft of water savings and by investigating a range of useful lives of the capital investment in the impervious-lined delivery canals down from the expected 20 years to as short as only 5 years. As should be expected, shorter-useful lives than the anticipated 20-year productive life resulted in higher cost estimates, lower energy savings than the predicted 100% of current average usage also increased cost estimates, and higher-than-expected energy savings contributed to lower cost estimates.

Similarly, **Tables 25** and **26** are a presentation of a range of cost estimates varying from $0.0000837 to $0.0002991 per BTU (and $0.286 to $1.021 per kwh) of energy savings around the baseline estimate of $0.0001824 per BTU ($0.622 per kwh). These calculated values were derived by varying the amount of energy used per ac-ft of water savings across a range as low as 80.0% up to 150.0% of the expected 141,908 BTUs (41.59 kwh) current average usage per ac-ft of water savings and by considering variations in the cost of the capital investment in the impervious-lined delivery canals varying from $200,000 less than the expected $696,565 up to $200,000 more than the expected amount. As should be expected, both lower-than-the-anticipated $696,565 capital costs and/or higher-than-expected energy savings contributed to lower cost estimates while both higher investment costs and/or lower energy savings than the predicted 141,908 BTUs (41.59 kwh) increased the cost estimates.

The final set of sensitivity analyses conducted for the costs of energy savings accounted for varying both the amount of energy used per ac-ft of water savings and the reduction in Rio Grande River diversions arising from water savings per mile of impervious-lined canal. **Tables 27** and **28** are illustrations of the results of varying those parameters from as low as 80.0% up to 150.0% of the expected 141,908 BTUs (41.59 kwh) current average usage per ac-ft of water savings and from as low as 50 ac-ft up to 300 ac-ft about the expected 215.33 ac-ft off-farm water savings per mile of impervious-lined canal. The resulting costs of energy savings estimates ranged from a high of $0.0005283 per BTU ($1.802 per kwh) down to a low of $0.0000419 per BTU ($0.321 per kwh). The lower cost estimates are associated with high energy usage per ac-ft of water savings and high off-farm water savings. In instances when this happens, the two factors combined contribute to substantial energy cost savings. The opposite effect is experienced with low energy usage per ac-ft of water savings and low off-farm water savings, i.e., higher costs estimates are calculated for these circumstances.

Component #3 -- 24" Pipelines Replacing Delivery Canals

The third component evaluated is the replacing of 5.66 miles of what are currently concrete-lined delivery canals located across six different sites in the District's canal delivery system with 24" pipelines. Results of the analysis of that component follow (**Table 29**).

<u>Quantities of Water and Energy Savings</u>

Critical values in the analyses are the quantities of water and energy anticipated being saved during the 49-year productive life of the pipelines.[21] On a nominal (i.e., non-discounted) basis, 119,460 ac-ft of irrigation water are projected to be saved; no M&I water savings are expected as a result of this project component. Thus, the total nominal water savings anticipated are 119,460 ac-ft over the 49-year productive life of this component (**Table 29**). Using the 4% discount rate previously discussed, those nominal savings translate into 50,029 ac-ft of real irrigation savings and 0.0 ac-ft of real M&I water savings, representing a total real water savings of 50,029 ac-ft (**Table 29**).

On a nominal (i.e., non-discounted) basis, 22,900,676,219 BTUs (6,711,804 kwh) of energy savings are projected to be saved in association with the forecast irrigation water savings (**Table 29**). Since there are no M&I-related energy savings, these values represent the total energy savings for this project component. Using the 4% discount rate previously discussed, those nominal savings translate into 9,590,544,355 BTUs (2,810,828 kwh) of real irrigation-related energy savings over the 49-year productive life of this component (**Table 29**).

---

21 As noted previously, the estimated useful life is 50 years instead of 49 years. RGIDECON© was developed to consider up to a maximum 50-year planning horizon, with the perspectives that projections beyond that length of time are largely discounted and also highly speculative. Allowing for the one-year installation period on the front end reduces to 49 years the time remaining for productive use of the asset during the 50-year planning period allowed within RGIDECON©.

Cost of Water Saved

One principal gauge of a proposed project component's merit is the estimated cost per ac-ft of water saved as a result of the project component's inception, purchase, installation, and implementation. Both deterministic results based on the expected values for all parameters integrated into the RGIDECON© assessments and sets of sensitivity analyses for several pairs of the data parameters are presented below for component #3, 24" pipelines.

NPV of Net Cost Stream. Accounting for all capital purchase and installation construction costs, changes in O&M expenditures, and credits for energy savings, the nominal total cost of the 50-year planning period for the 24" pipelines component of the District's project is $(763,236) (**Table 29**). Using the previously-identified discount rate of 6.125%, these nominal cost dollars translate into present-day, real costs of $660,310 (**Table 29**). This amount represents, across the total 50-year planning period, the total net costs, in 2002 dollars, of purchasing and installing the 24" pipelines as well as payment of the net changes in O&M expenditures. Note that the positive real-value amount of costs is substantially greater than the negative nominal-value amount. This result occurs because in the nominal-value amount, the savings accruing from reduced energy use in the lengthy planning period are sufficient to more than offset the initial investment costs. In the case of the real-value amount, however, the savings occurring during the latter years of the planning period are discounted significantly and thus do not offset as much of the initial investment costs.

NPV of All Water Savings. As detailed above, the total nominal water savings anticipated are 119,460 ac-ft (**Table 29**). The corresponding total real water savings expressed in 2002 water quantities are 50,029 ac-ft, assuming the previously-identified discount rate of 4.00% (**Table 29**).

Cost per Acre-Foot of Water Saved. Combining the real net cost estimate of $660,310 and the real water savings projection of 50,029 ac-ft, the estimated cost of saving one ac-ft of water using the 24" pipelines comprising this project component is $13.20 (**Table 29**). This value can be interpreted as the cost of leasing one ac-ft of water in year 2002. It is not the cost of purchasing the water right of one ac-ft. Following through with the economic and capital budgeting methodology presented in Rister et al. (2002) results, however, in the calculation of this same cost measure (i.e., $13.20). This value represents the costs per year in present-day dollars of saving one ac-ft of water each year into perpetuity through a continual replacement series of the 24" pipelines with all of the attributes previously indicated.

Sensitivity Results. The results presented above are predicated on numerous assumed values incorporated into the RGIDECON© analysis. Those assumed values and the logic for their assumed values are presented in prior sections. Here, attention is directed toward varying some of those values across a plausible range of possibilities, thereby seeking to identify the stability/instability of the estimated cost measure (i.e., $ costs per ac-ft of water saved) in response to changes in certain key parameters. The two-way Data Table feature of Excel (Walkenbach) is utilized to accomplish these sensitivity analyses whereby two parameters are varied and all others remain constant at the levels assumed for the baseline analysis.

The most critical assumption made in the baseline analysis is considered to be that pertaining to the amount of reduction in Rio Grande River diversions that will result from the purchase, installation, and implementation of the 24" pipelines in the canal delivery system. Thus, the cost per ac-ft of water-saved sensitivity analyses consist of varying the off-farm water-savings dimension[22] of that factor across a range of 50 to 300 ac-ft (including the baseline 215.33 ac-ft) per mile of 24" pipeline paired with variances in three other fundamental factors: (a) expected useful life of the investment; (b) initial capital investment costs; and (c) value of BTU savings (i.e., cost of energy). Results for these three sets of sensitivity analyses are presented in **Tables 30, 31,** and **32**, respectively.

Table 30 reveals a range of $8.30 to $185.75 cost per ac-ft of savings around the baseline estimate of $13.20. These calculated values were derived by varying the reduction in Rio Grande River diversions arising from off-farm water savings per mile of 24" pipeline from as low as 50 ac-ft up to 300 ac-ft about the expected 215.33 ac-ft and by investigating a range of useful lives of the 24" pipelines down from the expected 49 years to as short as only 10 years. As should be expected, shorter-useful lives than the anticipated 49-year productive life resulted in higher cost estimates, lower off-farm (and the assumed linked on-farm) water savings than the predicted 215.33 ac-ft per mile also increased cost estimates, and higher-than-expected water savings contributed to lower cost estimates.

Similarly, **Table 31** is a presentation of a range of cost estimates varying from $1.13 to $113.64 per ac-ft of savings around the baseline estimate of $13.20. These calculated values were derived by varying the reduction in Rio Grande River diversions arising from off-farm water savings per mile of 24" pipeline from as low as 50 ac-ft up to 300 ac-ft about the expected 215.33 ac-ft and by considering variations in the cost of the capital investment in the 24" pipelines varying from $500,000 less than the expected $941,393 up to $500,000 more than the expected amount. As should be expected, both lower-than-the-anticipated $941,393 capital costs and/or higher-than-expected water savings contributed to lower cost estimates, while both higher investment costs and/or lower off-farm (and the assumed linked on-farm) water savings than the predicted 3% value increased the cost estimates.

The final set of sensitivity analyses conducted for the costs of water savings accounted for varying both the reduction in Rio Grande River diversions arising from investment in 24" pipelines and the cost of energy. **Table 32** is an illustration of the results of varying those parameters from as low as 50 ac-ft up to 300 ac-ft about the expected 215.33 ac-ft per mile off-farm water savings and across a range of $0.08 to $0.12 per kwh energy costs about the assumed $0.10 per kwh level. The resulting costs of water savings estimates ranged from a high of $72.68 per ac-ft down to a low of $7.26 per ac-ft. The lower cost results are associated with high water savings and high energy costs – the two factors combined contribute to substantial energy cost savings which substantially offset both the initial capital costs of the 24" pipelines

---

22 Similar to the assumptions made in analyzing impervious-lining of delivery canals and per discussions with Blair and Halbert, on-farm water savings are linked to off-farm water savings within RGIDECON©'s assessment of this component of the proposed project. Thus, as the off-farm water savings associated with the 24" pipelines replacing currently concrete-lined delivery canals are varied in the sensitivity analyses, the on-farm savings also vary.

plus the anticipated changes in O&M expenses. The opposite effect is experienced with low energy usage per ac-ft of water savings and low water savings, i.e., higher costs estimates are calculated for these circumstances.

Cost of Energy Saved

Besides the estimated cost per ac-ft of water saved as a result of the 24" pipelines' inception, purchase, installation, and implementation, another issue of interest is the cost of energy savings. Reduced water diversions from the Rio Grande River will result as improved water management minimizes over-deliveries and increases head at on-farm delivery sites (thereby reducing on-farm water use). These reduced diversions and reduced use associated with the proposed 24" pipelines capital renovation result in less water being pumped, translating into energy savings. Additional energy savings are also projected for this component in association with reduced relift pumping. Both deterministic results based on the expected values for all parameters integrated into the RGIDECON© assessments and sets of sensitivity analyses for several pairs of the data parameters are presented below for component #3, 24" pipelines.

NPV of Net Cost Stream. Accounting for all capital purchase and installation construction costs, and changes in O&M expenditures, the nominal total cost of the 50-year planning period for the 24" pipelines component of the District's project is $419,417 (**Table 29**). Using the previously-identified discount rate of 6.125%, these nominal cost dollars translate into a present-day, real cost of $941,393 (**Table 29**). This amount represents, across the total 50-year planning period, the total net costs, in 2002 dollars, of purchasing and installing the 24" pipelines as well as payment of the net changes in O&M expenditures, ignoring the changes in energy costs and allowing no credits for the water savings.

NPV of All Energy Savings. As detailed above, the total nominal energy savings anticipated are 22,900,676,219 BTUs (9,590,544,355 kwh) (**Table 29**). The corresponding total real energy savings expressed in 2002 energy quantities are 9,590,544,355 BTUs (i.e., 2,810,828 kwh) over the 49-year productive life of this component, assuming the previously-identified discount rate of 4.00% (**Table 29**).

Cost per BTU & kwh Saved. Combining the real net cost estimate of $941,393 and the real energy savings projection of 9,590,544,355 BTUs (2,810,828 kwh), the estimated cost of saving one BTU of energy using the 24" pipelines comprising this project component is $0.0000982 ($0.335 per kwh) (**Table 29**). An interpretation of this value is that it is the cost of saving one BTU (kwh) of energy in year 2002. Following through with the economic and capital budgeting methodology presented in Rister et al. (2002) results, however, in calculation of this same cost measure (i.e., $0.0000982 per BTU or $0.335 per kwh). This value represents the costs per year in present-day dollars of saving one BTU (kwh) of energy into perpetuity through a continual replacement series of the 24" pipelines with all of the attributes previously indicated.

Sensitivity Results. As with the cost of water-savings estimates, the results presented above for energy savings are predicated on numerous assumed values incorporated into the RGIDECON© analysis. Those assumed values and the logic for their assumed values are presented in prior sections. Here, attention is directed towards varying some of those values across a plausible range of possibilities, thereby seeking to identify the stability/instability of the estimated cost measure (i.e., $ costs per BTU (or kwh) saved) in response to changes in certain key parameters. The two-way Data Table feature of Excel (Walkenbach) again is utilized to accomplish these sensitivity analyses whereby two parameters are varied and all others remain constant at the levels assumed for the baseline analysis.

The most critical assumption made in the baseline analysis in this respect is considered to be that pertaining to the amount of energy savings that will result from the purchase, installation, and implementation of the 24" pipelines in the canal delivery system. Thus, the cost per BTU (or kwh) of energy-saved sensitivity analyses consists of varying the amount of energy savings across a range of 80.0 percent up to 150.0 percent of the baseline 141,908 BTUs (41.59 kwh) current average usage per ac-ft of water savings paired with variances in three other fundamental factors: (a) expected useful life of the investment; (b) initial capital investment costs; and (c) off-farm water savings per mile of 24" pipeline. Results on a BTU and kwh basis for these three sets of sensitivity analyses are presented in **Tables 33** and **34, 35** and **36,** and **37** and **38**, respectively.

Tables 33 and **34** reveal a range of $0.0000654 to $0.0003228 cost per BTU (and $0.223 to $1.102 per kwh) of energy savings around the baseline estimate of $0.0000982 per BTU ($0.335 per kwh). These calculated values were derived by varying the amount of energy used per ac-ft of water savings across a range as low as 80.0% up to 150.0% of the expected 141,908 BTUs (41.59 kwh) current average usage per ac-ft of water savings and by investigating a range of useful lives of the capital investment in the 24" pipelines down from the expected 49 years to as short as only 10 years. As should be expected, shorter-useful lives than the anticipated 49-year productive life resulted in higher cost estimates, lower energy savings than the predicted 100% of current average usage also increased cost estimates, and higher-than-expected energy savings contributed to lower cost estimates.

Similarly, **Tables 35** and **36** are a presentation of a range of cost estimates varying from $0.0000307 to $0.0001879 per BTU (and $0.105 to $0.641 per kwh) of energy savings around the baseline estimate of $0.0000982 per BTU ($0.335 per kwh). These calculated values were derived by varying the amount of energy used per ac-ft of water savings across a range as low as 80.0% up to 150.0% of the expected 141,908 BTUs (41.59 kwh) current average usage per ac-ft of water savings and by considering variations in the cost of the capital investment in the 24" pipelines varying from $500,000 less than the expected $1,106,080 up to $500,000 more than the expected amount. As should be expected, both lower-than-the-anticipated $1,106,080 capital costs and/or higher-than-expected energy savings contributed to lower cost estimates while both higher investment costs and/or lower energy savings than the predicted 141,908 BTUs (41.59 kwh) increased the cost estimates.

The final set of sensitivity analyses conducted for the costs of energy savings accounted for varying both the amount of energy used per ac-ft of water savings and the reduction in Rio Grande River diversions arising from water savings per mile of 24" pipeline. **Tables 37** and **38** are illustrations of the results of varying those parameters from as low as 80.0% up to 150.0% of the expected 141,908 BTUs (41.59 kwh) current average usage per ac-ft of water savings and from as low as 50 ac-ft up to 300 ac-ft about the expected 215.33 ac-ft off-farm water savings per mile of 24" pipeline. The resulting costs of energy savings estimates ranged from a high of

$0.0002843 per BTU ($0.970 per kwh) down to a low of $0.0000507 per BTU ($0.173 per kwh). The lower cost estimates are associated with high energy usage per ac-ft of water savings and high off-farm (and the assumed linked on-farm) water savings – the two factors combined contribute to substantial energy cost savings. The opposite effect is experienced with low energy usage per ac-ft of water savings and low off-farm water savings, i.e., higher costs estimates are calculated for these circumstances.

Component #4 -- On-Farm Delivery-Site Meters

The fourth component evaluated is the installment and implementation of 400 on-farm delivery-site meters in the District's canal delivery system. Results of the analysis of that component follow (**Table 39**).

Quantities of Water and Energy Savings

Critical values in the analyses are the quantities of water and energy anticipated being saved during the 10-year productive life of the on-farm delivery-site meters. On a nominal (i.e., non-discounted) basis, 61,585 ac-ft of irrigation water are projected to be saved and another 0.0 ac-ft of M&I water savings are also estimated using the values presented earlier. Thus, the total nominal water savings anticipated are 61,585 ac-ft across the 10-year productive life of this component (**Table 39**). Using the 4% discount rate previously discussed, those nominal savings translate into 48,030 ac-ft of real irrigation savings and 0.0 ac-ft of real M&I water savings, representing a total real water savings of 48,030 ac-ft (**Table 39**).

On a nominal (i.e., non-discounted) basis, 8,739,428,083 BTUs of energy savings are projected to be saved in association with the forecast irrigation water savings. No BTUs of nominal energy saving are expected as a result of the potential M&I water savings. Thus, the total nominal energy savings anticipated are 8,739,428,083 BTUs (2,561,380 kwh) over the 10-year productive life of this component (**Table 39**). Using the 4% discount rate previously discussed, those nominal savings translate into 6,815,825,995 BTUs of real irrigation-related energy savings and 0 BTUs of real M&I-related energy savings, representing a total real savings of 6,815,825,995 BTUs (1,997,604 kwh) (**Table 39**).

Cost of Water Saved

One principal gauge of a proposed project component's merit is the estimated cost per ac-ft of water saved as a result of the project component's inception, purchase, installation, and implementation. Both deterministic results based on the expected values for all parameters integrated into the RGIDECON© assessments and sets of sensitivity analyses for several pairs of the data parameters are presented below for component #4, on-farm delivery-site meters.

NPV of Net Cost Stream. Accounting for all capital purchase and installation construction costs, changes in O&M expenditures, and credits for energy savings, the nominal total cost of the 11-year planning period for the on-farm delivery-sites meters constituting this component of the District's project is $1,225,445 (**Table 39**). Using the previously-identified discount rate of 6.125%, these nominal cost dollars translate into present-day, real costs of

\$1,042,775 (**Table 39**). This amount represents, across the total 11-year planning period, the total net costs, in 2002 dollars, of purchasing and installing the on-farm delivery-sites meters as well as payment of the net changes in O&M expenditures.

NPV of All Water Savings. As detailed above, the total nominal water savings anticipated are 61,585 ac-ft (**Table 39**). The corresponding total real water savings expressed in 2002 water quantities are 48,030 ac-ft, assuming the previously-identified discount rate of 4.00% (**Table 39**).

Cost per Acre-Foot of Water Saved. Combining the real net cost estimate of \$1,042,775 and the real water savings projection of 48,030 ac-ft, the estimated cost of saving one ac-ft of water using the on-farm delivery-sites meters technology comprising this project component is \$21.71 (**Table 39**). This value can be interpreted as the cost of leasing one ac-ft of water in year 2002. It is not the cost of purchasing the water right of one ac-ft. Following through with the economic and capital budgeting methodology presented in Rister et al. (2002) results, however, in this same cost measure (i.e., \$21.71), representing the costs per year in present-day dollars of saving one ac-ft of water each year into perpetuity through a continual replacement series of the on-farm delivery-site meters with all of the attributes previously indicated.

Sensitivity Results. The results presented above are predicated on numerous assumed values incorporated into the RGIDECON© analysis. Those assumed values and the logic for their assumed values are presented in prior sections. Here, attention is directed toward varying some of those values across a plausible range of possibilities, thereby seeking to identify the stability/instability of the estimated cost measure (e.g., \$ costs per ac-ft of water saved) in response to changes in certain key parameters. The two-way Data Table feature of Excel (Walkenbach) is utilized to accomplish these sensitivity analyses whereby two parameters are varied and all others remain constant at the levels assumed for the baseline analysis.

The most critical assumption made in the baseline analysis is considered to be that pertaining to the amount of reduction in Rio Grande River diversions that will result from the purchase, installation, and implementation of the on-farm delivery-site meters in the canal delivery system. Thus, the cost per ac-ft of water-saved sensitivity analyses consist of varying the on-farm water savings across a range of 1.0 percent up to 50.0 percent (including the baseline 27.0 percent) of the District's historic five-year (1997-2001) average water-usage level paired with variances in three other fundamental factors: (a) expected useful life of the investment; (b) initial capital investment costs; and (c) value of BTU savings (i.e., cost of energy). Results for these three sets of sensitivity analyses are presented in **Tables 40, 41,** and **42**, respectively.

Table 40 reveals a range of \$9.81 to \$1,265.02 cost per ac-ft of savings around the baseline estimate of \$21.71. These calculated values were derived by varying the percent reduction in Rio Grande River diversions arising from on-farm water savings across a range of 1.00% to 50.0% about the expected 27.0% and by investigating a range of useful lives of the on-farm delivery-site meters down from the expected 10 years to as short as only 5 years. As should be expected, shorter-useful lives than the anticipated 10-year productive life resulted in higher cost estimates, lower on-farm water savings than the predicted 27% also increased cost estimates, and higher-than-expected water savings contributed to lower cost estimates.

Similarly, **Table 41** is a presentation of a range of cost estimates varying from \$7.56 to \$806.76 per ac-ft of savings around the baseline estimate of \$21.71. These calculated values were derived by varying the percent reduction in Rio Grande River diversions arising from on-farm water savings across a range of 1.0% to 50.0% about the expected 27.0% and by considering variations in the cost of the capital investment in the on-farm delivery-site meters varying from \$200,000 less than the expected \$649,816 up to \$200,000 more than the expected amount. As should be expected, both lower-than-the-anticipated \$649,816 capital costs and/or higher-than-expected water savings contributed to lower cost estimates while both higher investment costs and/or lower off-farm water savings than the predicted 27% increased the cost estimates.

The final set of sensitivity analyses conducted for the costs of water savings accounted for varying both the percent reduction in Rio Grande River diversions arising on-farm water savings and the cost of energy. **Table 42** is an illustration of the results of varying those parameters from as low as 1.0% up to 50.0% about the expected 27.0% off-farm water savings and across a range of \$0.08 to \$0.12 per kwh energy costs about the assumed \$0.10 per kwh level. The resulting costs of water savings estimates ranged from a high of \$695.16 per ac-ft down to a low of \$8.98 per ac-ft. Both higher-than-anticipated water savings and higher-than-expected energy costs contributed to lower cost of water savings estimates while both lower-than-anticipated water savings and lower-than expected energy costs increased the cost of water savings estimates.

<u>Cost of Energy Saved</u>

Besides the estimated cost per ac-ft of water saved as a result of the on-farm delivery-site meters' inception, purchase, installation, and implementation, another issue of interest is the cost of energy savings. Reduced water diversions from the Rio Grande River will result as improved water management minimizes over-deliveries and increases head at on-farm delivery sites (thereby reducing on-farm water use). These reduced diversions and reduced use associated with the proposed on-farm delivery-site meters capital renovation result in less water being pumped, translating into energy savings. Both deterministic results based on the expected values for all parameters integrated into the RGIDECON© assessments and sets of sensitivity analyses for several pairs of the data parameters are presented below for component #4, on-farm delivery-site meters.

<u>NPV of Net Cost Stream</u>. Accounting for all capital purchase and installation construction costs, and changes in O&M expenditures, the nominal total cost of the 11-year planning period for the on-farm delivery-site meters component of the District's project is \$1,518,066 (**Table 39**). Using the previously-identified discount rate of 6.125%, these nominal cost dollars translate into a present-day, real cost of \$1,242,535 (**Table 39**). This amount represents, across the total 11-year planning period, the total net costs, in 2002 dollars, of purchasing and installing the on-farm delivery-site meters as well as payment of the net changes in O&M expenditures, ignoring the changes in energy costs and allowing no credits for the water savings.

<u>NPV of All Energy Savings</u>. As detailed above, the total nominal energy savings anticipated are 8,739,428,083 BTUs (2,561,380 kwh) (**Table 39**). The corresponding total real energy savings expressed in 2002 energy quantities are 6,815,825,995 BTUs (1,997,604 kwh), assuming the previously-identified discount rate of 4.00% (**Table 39**).

<u>Cost per BTU & kwh Saved</u>. Combining the real net cost estimate of $1,242,535 and the real energy savings projection of 6,815,825,995 BTUs (1,997,604 kwh), the estimated cost of saving one BTU of energy using the on-farm delivery-site meters technology comprising this project component is $0.0001823 ($0.622 per kwh) (**Table 39**). An interpretation of this value is that it is the cost of saving one BTU (kwh) of energy in year 2002. Following through with the economic and capital budgeting methodology presented in Rister et al. (2002) results, however, in this same cost measure (i.e., $0.0001823 per BTU or $0.622 per kwh), representing the <u>costs per year</u> in present-day dollars of <u>saving one BTU (kwh) of energy</u> into perpetuity through a continual replacement series of the on-farm delivery-site meters with all of the attributes previously indicated.

<u>Sensitivity Results</u>. As with the cost of water-savings estimates, the results presented above for energy savings are predicated on numerous assumed values incorporated into the RGIDECON© analysis. Those assumed values and the logic for their assumed values are presented in prior sections. Here, attention is directed toward varying some of those values across a plausible range of possibilities, thereby seeking to identify the stability/instability of the estimated cost measure (i.e., $ costs per BTU (or kwh) saved) in response to changes in certain key parameters. The two-way Data Table feature of Excel (Walkenbach) again is utilized to accomplish these sensitivity analyses whereby two parameters are varied and all others remain constant at the levels assumed for the baseline analysis.

The most critical assumption made in the baseline analysis in this respect is considered to be that pertaining to the amount of energy savings that will result from the purchase, installation, and implementation of the on-farm delivery-site meters in the canal delivery system. Thus, the cost per BTU (or kwh) of energy-saved sensitivity analyses consists of varying the amount of energy savings across a range of 80.0% up to 150.0% of the baseline 141,908 BTUs (41.59 kwh) current average usage per ac-ft of water savings paired with variances in three other fundamental factors: (a) expected useful life of the investment; (b) initial capital investment costs; and (c) percent water savings of current on-farm use on 50% of irrigation water. Results on a BTU and kwh basis for these three sets of sensitivity analyses are presented in **Tables 43** and **44**, **45** and **46**, and **47** and **48**, respectively.

Tables 43 and **44** reveal a range of $0.0001215 to $0.0004152 cost per BTU (and $0.415 to $1.417 per kwh) of energy savings around the baseline estimate of $0.0001823 per BTU ($0.622 per kwh). These calculated values were derived by varying the amount of energy used per ac-ft of water savings across a range as low as 80.0% up to 150.0% of the expected 141,908 BTUs (41.59 kwh) current average usage per ac-ft of water savings and by investigating a range of useful lives of the capital investment in the on-farm delivery-site meters down from the expected 10 years to as short as only 5 years. As should be expected, shorter-useful lives than the anticipated 10-year productive life resulted in higher cost estimates, lower energy savings than the predicted 100% of current average usage also increased cost estimates, and higher-than-expected energy savings contributed to lower cost estimates.

Similarly, **Tables 45** and **46** are a presentation of a range of cost estimates varying from \$0.0001020 to \$0.0002646 per BTU (and \$0.348 to \$0.903 per kwh) of energy savings around the baseline estimate of \$0.0001823 per BTU (\$0.622 per kwh). These calculated values were derived by varying the amount of energy used per ac-ft of water savings across a range as low as 80.0% up to 150.0% of the expected 141,908 BTUs (41.59 kwh) current average usage per ac-ft of water savings and by considering variations in the cost of the capital investment in the on-farm delivery-site meters varying from \$200,000 less than the expected \$649,816 up to \$200,000 more than the expected amount. As should be expected, both lower-than-the-anticipated \$649,816 capital costs and/or higher-than-expected energy savings contributed to lower cost estimates while both higher investment costs and/or lower energy savings than the predicted 141,908 BTUs (41.59 kwh) increased the cost estimates.

The final set of sensitivity analyses conducted for the costs of energy savings accounted for varying both the amount of energy used per ac-ft of water savings and the percent reduction in Rio Grande River diversions arising from on-farm water savings. **Tables 47** and **48** are illustrations of the results of varying those parameters from as low as 80.0% up to 150.0% of the expected 141,908 BTUs (41.59 kwh) current average usage per ac-ft of water savings and from as low as 1.0% up to 50.0% about the expected 27.0% off-farm water savings. The resulting cost of energy savings estimates ranged from a high of \$0.0061527 per BTU (\$20.993 per kwh) down to a low of \$0.0000656 per BTU (\$0.224 per kwh). The lower cost estimates are associated with high energy usage per ac-ft of water savings and high off-farm water savings – the two factors combined contribute to substantial energy cost savings. The opposite effect is experienced with low energy usage per ac-ft of water savings and low off-farm water savings, i.e., higher costs estimates are calculated for these circumstances.

Economic and Financial Evaluation Results Aggregated Across Components

According to Bureau of Reclamation management (Shaddix), a comprehensive, aggregated measure is required to assess the overall potential performance of a proposed project consisting of multiple components. That is, projects are to be evaluated in the form submitted by Districts and when two or more components comprise a project, one general measure should be determined to represent the total project. Discussions of such comprehensive measures follow for both the cost of water saved and the cost of energy saved. ***Aggregations of only the baseline cost measures are presented; that is, the various sensitivity analyses previously presented and discussed for each individual project component are not duplicated here.***

Following the methodology documented in Rister et al. (2002), the cost measures calculated for the individual components are first converted into 'annuity equivalents,' prior to being aggregated into the comprehensive measures. The 'annuity equivalent' calculations facilitate comparison and aggregation of capital projects with unequal useful lives, effectively serving as development of a common denominator. The finance aspect of the 'annuity equivalent' calculation as it is used in the RGIDECON© analyses is such that it represents an annual cost savings associated with one unit of water (or energy) each year extended indefinitely into the future. Zero salvage values and continual replacement of the respective technologies (i.e., canal meters and telemetry equipment, impervious-lining of delivery canals, 24" pipelines replacing delivery canals, and on-farm delivery-site meters) with similar capital items as their useful life ends are assumed.

Cost of Water Saved

Table 49 provides aggregated information relating to the cost of water saved, relying on the baseline deterministic information presented in the previous discussion sections for the canal meters and telemetry equipment, impervious-lining of delivery canals, 24" pipelines replacing delivery canals, and on-farm delivery-site meters, respectively. The individual component measures are displayed in the table and then aggregated in the far-right column, indicating that the overall cost of water saved is **$31.37 per ac-ft**.

<u>Canal Meters and Telemetry Equipment</u>

Recall that the initial capital investment associated with the 'Canal Meters and Telemetry Equipment' capital renovation is $757,538 in 2002 nominal dollars (**Table 3**). Combining that cost with the changes in O&M expenditures over the 16-year planning horizon and calculating the net present value (NPV) of that flow of funds contributes to the $1,893,594 value noted at the top of the 'Canal Meters and Telemetry Equipment' column in **Table 49.** The nominal water savings anticipated during the 16-year planning period total 30,330 ac-ft; discounted into a real 2002 value, those savings are estimated to be 21,617 ac-ft (**Table 9**). Converting the real 2002 values into annuity equivalents per the methodology presented in Rister et al. 2002 results in an annual cost estimate of $188,987 to achieve 2,157 ac-ft of water savings per year (**Table 49**). Dividing the first annuity estimate by the second annuity estimate results in an annuity cost estimate of $87.60 per ac-ft of water savings for the canal meters and telemetry equipment capital renovation (**Table 49**).

<u>Impervious-Lined Delivery Canals</u>

Similarly, the initial capital investment associated with the 'Impervious-Lined Delivery Canals' capital renovation is $696,565 in 2002 nominal dollars (**Table 5**). Combining that cost with the changes in O&M expenditures over the 21-year planning horizon and calculating the net present value (NPV) of that flow of funds contributes to the $535,049 value noted at the top of the 'Impervious-Lined Delivery Canals' column in **Table 49.** The nominal water savings anticipated during the 21-year planning period total 29,478 ac-ft; discounted into a real 2002 value, those savings are estimated to be 18,343 ac-ft (**Table 19**). Converting both of the real 2002 values into annuity equivalents per the methodology presented in Rister et al. 2002 results in an annual cost estimate of $45,961 to achieve 1,576 ac-ft of water savings per year (**Table 49**). Dividing the first annuity estimate by the second annuity estimate results in the annuity cost estimate of $29.17 per ac-ft of water savings for the impervious-lined delivery canals capital renovation (**Table 49**).

24" Pipelines

The initial capital investment associated with the '24" Pipelines' capital renovation is $1,106,080 in 2002 nominal dollars (**Table 7**). Combining that cost with the changes in O&M expenditures over the 50-year planning horizon and calculating the net present value (NPV) of that flow of funds contributes to the $660,310 value noted at the top of the '24" Pipelines' column in **Table 49.** The nominal water savings anticipated during the 50-year planning period total 119,460 ac-ft; discounted into a real 2002 value, those savings are estimated to be 50,029 ac-ft (**Table 29**). Converting both of the real 2002 values into annuity equivalents per the methodology presented in Rister et al. 2002 results in an annual cost estimate of $42,626 to achieve 3,230 ac-ft of water savings per year (**Table 49**). Dividing the first annuity estimate by the second annuity estimate results in the annuity cost estimate of $13.20 per ac-ft of water savings for the 24" pipelines replacing delivery canals capital renovation (**Table 49**).

On-Farm Delivery-Site Meters

The initial capital investment associated with the 'On-Farm Delivery-Site Meters' capital renovation is $649,816 in 2002 nominal dollars (**Table 8**). Combining that cost with the changes in O&M expenditures over the 11-year planning horizon and calculating the net present value (NPV) of that flow of funds contributes to the $1,042,775 value noted at the top of the 'On-Farm Delivery-Site Meters' column in **Table 49.** The nominal water savings anticipated during the 11-year planning period total 61,585 ac-ft; discounted into a real 2002 value, those savings are estimated to be 48,030 ac-ft (**Table 39**). Converting both of the real 2002 values into annuity equivalents per the methodology presented in Rister et al. 2002 results in an annual cost estimate of $133,063 to achieve 6,129 ac-ft of water savings per year (**Table 49**). Dividing the first annuity estimate by the second annuity estimate results in the annuity cost estimate of $21.71 per ac-ft of water savings for the on-farm delivery-site meters capital renovation (**Table 49**).

Aggregate Measure of Cost of Water Savings

Combining the costs of the four components (i.e., canal meters and telemetry equipment, impervious-lining of delivery canals, 24" pipelines replacing concrete-lined delivery canals, and on-farm delivery-site meters) of the District's proposed project results in a total NPV net cost (i.e., both initial investments and changes in O&M expenditures) estimate of $4,131,728 which translates into an annuity cost equivalent of $410,637 per year (**Table 49**). The total NPV of water savings is 138,019 ac-ft, representing an annuity equivalent of **13,092 ac-ft of water savings** (**Table 49**). Performing the same math as used in calculating the costs of water savings for the individual components (i.e., dividing the annuity of the net cost stream by the annuity amount of water savings) produces the **$31.37 per ac-ft** water savings aggregate cost measure (**Table 49**).

Cost of Energy Saved

Table 50 provides aggregated information relating to the cost of energy saved, relying on the baseline deterministic information presented in the previous discussion sections for the canal meters and telemetry equipment, impervious-lining of delivery canals, 24" pipelines replacing concrete-lined delivery canals, and on-farm delivery-site meters, respectively. The individual component measures are displayed in the table and then aggregated in the far-right column, indicating that the overall cost of water saved is **$0.0002253 per BTU (or $0.769 per kwh)**.

Canal Meters and Telemetry Equipment

As reiterated above in the 'Cost of Water Saved' section, the initial capital investment associated with the 'Canal Meters and Telemetry Equipment' capital renovation is $757,538 in 2002 nominal dollars (**Table 3**). Combining that cost with the changes in O&M expenditures over the 16-year planning horizon and calculating the net present value (NPV) of that flow of funds contributes to the $1,983,501 value noted at the top of the 'Canal Meters and Telemetry Equipment' column in **Table 50**. This cost estimate is higher than the $1,893,594 noted previously in **Table 49** because the energy savings considered in the 'Cost of Water Saved' calculations are ignored when calculating the 'Cost of Energy Saved.' The nominal energy savings anticipated during the 16-year planning period total 4,304,093,170 BTUs (1,261,457 kwh) (**Table 9**). Discounted into a real 2002 value, those savings are estimated to be 3,067,600,987 BTUs (899,062 kwh) (**Table 9**). Converting both of the real 2002 values into annuity equivalents per the methodology presented in Rister et al. 2002 results in an annual cost estimate of $197,960 to achieve 306,156,742 BTUs (89,729 kwh) of energy savings per year (**Table 50**). Dividing the first annuity estimate by the second annuity estimate results in the annuity cost estimate of $0.0006466 per BTU ($2.206 per kwh) of energy savings for the canal meters and telemetry equipment capital renovation (**Table 50**).

Impervious-Lined Delivery Canals

The initial capital investment associated with the 'Impervious-Lined Delivery Canals' capital renovation is $696,565 in 2002 nominal dollars (**Table 5)**. Combining that cost with the changes in O&M expenditures over the 21-year planning horizon and calculating the net present value (NPV) of that flow of funds contributes to the $641,438 value noted at the top of the 'Impervious-Lined Delivery Canals' column in **Table 50.** This value is again higher than the corresponding $535,049 value in **Table 49** because of the ignoring of energy savings when calculating the 'Cost of Energy Saved.' The nominal energy savings anticipated during the 21-year planning period total 5,651,015,214 BTUs (1,656,218 kwh) (**Table 19**). Discounted into a real 2002 value, those savings are estimated to be 3,516,444,182 BTUs 1,030,611 kwh) (**Table 19**). Converting both of the real 2002 values into annuity equivalents per the methodology presented in Rister et al. 2002 results in an annual cost estimate of $55,100 to achieve 302,063,807 BTUs (88,530 kwh) of energy savings per year (**Table 50**). Dividing the first annuity estimate by the second annuity estimate results in the annuity cost estimate of $0.0001824 per BTU ($0.622 per kwh) of energy savings for the impervious-lined delivery canals capital renovation (**Table 50**).

24" Pipelines

The initial capital investment associated with the '24" Pipelines' capital renovation is $1,106,080 in 2002 nominal dollars (**Table 7)**. Combining that cost with the changes in O&M

expenditures over the 50-year planning horizon and calculating the net present value (NPV) of that flow of funds contributes to the $941,393 value noted at the top of the '24" Pipelines' column in **Table 50.** This value is again higher than the corresponding $660,310 value in **Table 49** because of the ignoring of energy savings when calculating the 'Cost of Energy Saved.' The nominal energy savings anticipated during the 50-year planning period total 22,900,676,219 BTUs (6,711,804 kwh) (**Table 29**). Discounted into a real 2002 value, those savings are estimated to be 9,590,544,355 BTUs (2,810,828 kwh) (**Table 29**). Converting both of the real 2002 values into annuity equivalents per the methodology presented in Rister et al. 2002 results in an annual cost estimate of $60,771 to achieve 619,107,843 BTUs (181,450 kwh) of energy savings per year (**Table 50**). Dividing the first annuity estimate by the second annuity estimate results in the annuity cost estimate of $0.0000982 per BTU ($0.335 per kwh) of energy savings for the 24" pipelines replacing delivery canals capital renovation (**Table 50**).

<u>On-Farm Delivery-Site Meters</u>

The initial capital investment associated with the 'On-Farm Delivery-Site Meters' capital renovation is $649,816 in 2002 nominal dollars (**Table 8**). Combining that cost with the changes in O&M expenditures over the 11-year planning horizon and calculating the net present value (NPV) of that flow of funds contributes to the $1,242,535 value noted at the top of the 'On-Farm Delivery-Site Meters' column in **Table 50**. This cost estimate is higher than the $1,042,775 noted previously in **Table 49** because the energy savings considered in the 'Cost of Water Saved' calculations are ignored when calculating the 'Cost of Energy Saved.' The nominal energy savings anticipated during the 11-year planning period total 8,739,428,083 BTUs (2,561,380 kwh) (**Table 39**). Discounted into a real 2002 value, those savings are estimated to be 6,815,825,995 BTUs (1,997,604 kwh) (**Table 39**). Converting both of the real 2002 values into annuity equivalents per the methodology presented in Rister et al. 2002 results in an annual cost estimate of $158,553 to achieve 869,731,963 BTUs (254,904 kwh) of energy savings per year (**Table 50**). Dividing the first annuity estimate by the second annuity estimate results in the annuity cost estimate of $0.0001823 per BTU ($0.622 per kwh) of energy savings for the on-farm delivery-site meters capital renovation (**Table 50**).

<u>Aggregate Measure of Cost of Energy Savings</u>

Combining the costs of the four components (i.e., canal meters and telemetry equipment, impervious-lining of delivery canals, 24" pipelines replacing concrete-lined delivery canals, and on-farm delivery-site meters) of the District's proposed project results in a total NPV net cost (i.e., both initial investments and changes in O&M expenditures) estimate of $4,808,867 which translates into an annuity cost equivalent of $472,384 per year (**Table 50**). The total NPV of energy savings is 22,990,415,520 BTUs, representing an annuity equivalent of **2,097,060,356 BTUs (614,613 kwh)** of energy savings. Performing the same math as used in calculating the costs of energy savings for the individual components (i.e., dividing the annuity of the net cost stream by the annuity amount of energy savings) produces the **$0.0002253 per BTU ($0.769 per kwh)** of energy savings aggregate cost measure (**Table 50**).

Limitations

The protocol and implementation of the analyses reported in this report are robust, providing insightful information regarding the potential performance of the project proposed by the District. There are limitations, however, to what the results are and are not and how they should and should not be used. The discussion below addresses such issues.

- The analyses are conducted from a District perspective, ignoring income and expense impacts on both water users (i.e., farmers and M&I consumers) and third-party beneficiaries (i.e., the indirect economic impact effects). The spatial component and associated efficiency issues of 28 independent Districts supplying water to an array of agricultural, municipal, and industrial users in a relatively concentrated area are cast aside.

- The analyses are *pro forma* budgeting in nature, based on forecasts of events and economic forces extending into the future several years. Obviously, there is imperfect information about such conditions, contributing to a degree of uncertainty as to the appropriate exact input values. Necessarily, such uncertainty contributes to some ambiguity surrounding the final result measures.

- Constrained financial resources, limited data availability, and a defined time horizon prohibit (a) extensive field experimentation to document all of the engineering- and water-related parameters; and (b) prolonged assimilation of economic costs and savings parameters. The immediate and readily-apparent status of needs for improvement across a wide array of potential projects and the political atmosphere characterizing the U.S.-Mexico water treaty situation discourage a slow, deliberate, elaborate, extensive evaluation process.

- Although the analyses' framework is deterministic, sensitivity analyses are included for several of the dominant parameters in recognition of the prior two limitations.

- Beyond the sensitivity analyses mentioned above, there is no accounting for risk in these analyses.

- The economic appraisal of the proposed project is objective and relatively simple in nature, providing straightforward estimates of the cost of water and energy saved. No benefit value of the water savings is conjectured to be forthcoming from the proposed project, i.e., a complete cost-benefit procedure is not applied. Consequently, the comprehensive issue of the net value of the proposed project is not addressed in this report.

- The project is evaluated as proposed, consisting in this case of multiple (i.e., four) components. While such components are assumed mutually independent in the analyses, their joint potential is the bottomline result presented in this report as opposed to them being identified as separate and distinct renovation alternatives. That is, per guidance from Bureau of Reclamation management (Shaddix), the project is appraised as proposed by the District, with the four components viewed as an 'all or none' opportunity.

- An individual project proposed by a District is evaluated in the positive, objective form noted earlier independent of other District's proposals. Should there be cause for comparison of potential performance across two or more proposed projects, such appraisals need to be conducted exogenous to this report. The results presented in the main body of this report could be useful for such prioritization processes, however, as discussed in Rister et al. (2002).

- No possible capital renovations to the District besides those contained in the designated proposal are evaluated in comparison to the components of this project proposal. That is, while there may be other more economical means of saving water and energy within the District, those methods are not evaluated here.

- The analyses of the proposed project are conditional on existing District, Rio Grande Valley, State, and Federal infrastructure, policies (e.g., Farm Bill, U.S.-Mexico Water Treaty, etc.), and other institutional parameters (e.g., Domestic, Municipal, and Industrial (DMI) reserve levels, water rights ownership and transfer policies, priority of M&I rights, etc.). The implicit assumption is that the 28 Irrigation Districts in the Rio Grande Valley will retain their autonomy, continuing to operate independently, with any future collaboration, merger, other form of reorganization, and/or change in institutional policies to have no measurable impacts on the performance of the proposed project.

- The projects analyzed in this and other forthcoming reports are limited to those authorized by the Congress as a result of processes initiated by individual Districts or as proposed for other funding should that occur. That is, no comprehensive *a priori* priority systematic plan has been developed whereby third-party entities identify and prioritize projects on a Valley-wide basis, thereby providing preliminary guidance on how best to allocate appropriated funding in the event such funds are limited through time.

While such caveats indicate real limitations, they should not be interpreted as negating of the results contained in this report. These results are bonafide and conducive for use in the appraisal of the proposed projects affiliated with Public Law 106-576 legislation as well as those projects being proposed to the BECC and NADBank. The above issues are worthy of consideration for future research and programs of work, but should not be misinterpreted and/or misapplied to the extent of halting efforts underway at this time.

Recommended Future Research

The analyses presented in this report are conditioned on the best information available, subject to the array of resource limitations and other problematic issues previously mentioned. Considering those circumstances, the results are highly useful for the Bureau of Reclamation's appraisal and prioritization of the several Rio Grande Basin projects already or potentially authorized by the Congress or submitted in a formal manner. Similarly, the results attend to the needs of BECC and NADBank in their review and certification of proposed projects. Nonetheless, there are opportunities for additional research and/or other programs of work that would provide valuable insight in a holistic manner of the greater issue of water resource management in the immediate Rio Grande Valley Basin area and beyond. These issues are related in large part to addressing the concerns noted in the "Limitations" section.

- A comprehensive economic impact study would provide an overall impact of the proposed renovations, thereby enhancing the economic strength of the analyses. Necessarily, it is suggested such an effort encompass a full cost-benefit assessment and potential alterations in cropping patterns, impacts of projected urban growth, distribution of water use across the Basin, etc. It is relevant to note that evaluation of Federal projects often employ a national perspective and consider such local impacts negligible. A more-localized perspective in the level of analyses results in greater benefits being estimated along with increased attention to the identity of 'winners' and 'losers' in the resulting adjustments that are anticipated. For example, while on a national perspective the issue of the 1.7 million ac-ft of water now owed to the U.S. may not be a high-priority issue, it certainly is viewed as a critical issue within the immediate Rio Grande Valley area.

- A continued, well-defined program akin to the Federal Rio Grande Basin Initiative would enhance information availability in regards to the engineering- and water-related parameters related economic costs and savings parameters associated with capital renovations using existing and future technologies. It would be valuable to extend such efforts to District infrastructure and farm operations. A similar research agenda should be developed and implemented for the M&I sector of water users.

- Evaluating economies of size for optimal District operations, with intentions of recognizing opportunities for eliminating duplication of expensive capital items (e.g., pumping plants) and redundant O&M services would provide insight into potential for greater efficiency.

- Integration of risk would be useful in future analyses, including incorporation of stochastic elements for and correlation among the numerous parameters of consequence affecting the costs of water and energy measurements of interest. Such recognition of risk could extend beyond the immediate District factors to also allow for variance in the DMI reserve level policy under stochastic water availability scenarios and/or consideration of the effects of agricultural water rights being purchased by M&I users and converted, albeit at a less than 100% rate, from 'soft' to 'firm' rates.

- Attention is needed in identifying an explicit prioritization process for ranking projects competing for limited funds. Such a process could attend to distinguishing distinct components comprising a single project into separate projects and provide for consideration of other opportunities besides those proposed by an individual District whereby such latter projects are identified in the context of the total Rio Grande Basin as opposed to an individual District. Consideration of the development of an economic mixed-integer programming model (Agrawal and Heady) is suggested as a reasonable and useful complement to ongoing and future-anticipated engineering activities. Such an effort would provide a focal point for identifying and assimilating data necessary for both individual and comprehensive, Valley-wide assessments in a timely fashion.

- The issues of water rights ownership and transfer policies, priority of M&I rights, sources and costs of push water, etc. are admittedly contentious, but still should not be ignored as M&I demands accelerate and agricultural economic dynamics affect current and future returns to water used in such ventures.

- Development of a Valley- or Basin-wide based strategic capital investment plan is suggested, thereby providing preliminary guidance on how best to allocate appropriated funding; both agricultural and M&I use should be considered in such a plan.

- Detailed studies of Districts' water pricing (e.g., flat rates versus volumetric) policies, effects of water rights, conventions on sales and leasing of water rights, and various other issues relating to economic efficiency of water use could contribute insights on improved incentives for water conservation and capital improvement financing.

- Consideration of including M&I users as responsible parties for financing capital improvements is warranted.

Clearly, this is not a comprehensive list of possible activities germane to water issues in the Rio Grande Basin and/or the management of Irrigation Districts therein. The items noted could facilitate development, however, of proactive approaches to addressing current and emerging issues in the Rio Grande Basin area and beyond.

Summary and Conclusions

The District's project proposal to NADBank consists of four components: 105 meters to be installed at 70 locations throughout the delivery system, 3.26 miles of impervious-lined delivery canals replacing four segments of currently concrete-lined delivery canals, 5.66 miles of 24" pipelines replacing six segments of currently concrete-lined delivery canals, and 400 on-farm delivery-site meters. The required capital investment costs are $757,538, $696,565, $1,106,080, and $649,816, respectively, representing a total cost of $3,209,999. A one-year installation period is expected for each of the four components comprising this total capital renovation project. Anticipated useful lives of the four components are 15 years, 20 years, 49 years, and 10 years, respectively. Net annual O&M expenditures are expected to increase in association with both (a) the canal meters and telemetry equipment and (b) the on-farm delivery-site meters. Net decreases in annual O&M expenditures are expected, however, with respect to the replacing of currently concrete-lined delivery canals with impervious-lined delivery canals and with 24" pipelines (**Tables 3, 5, 7,** and **8**).

Only off-farm water savings are predicted to be forthcoming from the canal meters and telemetry equipment, with the nominal total being 30,330 ac-ft over the 15-year productive life of this component and the real 2002 total being 21,617 ac-ft (**Table 9**). Comparable water-savings numbers associated with the 3.26 miles of impervious-lined delivery canals occurring from both off- and on-farm sources are 29,478 nominal ac-ft over the 20-year productive life of this component and 18,343 real 2002 ac-ft (**Table 19**). Water-savings numbers associated with the 5.66 miles of 24" pipelines occurring from both off- and on-farm sources are 119,460 nominal ac-ft over the 49-year productive life of this component and 50,029 real 2002 ac-ft (**Table 29**). The water-savings numbers associated with the 400 on-farm delivery-site meters occurring from on-farm sources are 61,585 nominal ac-ft over the 10-year productive life of this component and 48,030 real 2002 ac-ft (**Table 39**). Across the total project, nominal water savings are 240,853 ac-ft (**Tables 9**, **19**, **29**, and **39**) and real 2002 savings are 138,019 ac-ft. On an average, annual, real basis, this amounts to **13,092 ac-ft** totaled across the four components (**Table 49)**.

Energy savings estimates associated with the canal meters and telemetry equipment are 4,304,093,170 BTUs (1,261,457 kwh) in nominal terms over the 15-year productive life of this component and 3,067,600,987 BTUs (899,062 kwh) in real 2002 terms (**Table 9**). Similar estimates associated with the impervious-lined delivery canals are 5,651,015,214 BTUs (1,656,218 kwh) nominal energy savings over the 20-year productive life of this component and 3,516,444,182 BTUs (1,030,611 kwh) real energy savings (**Table 19**). The same estimates associated with the 24" pipelines are 22,900,676,219 BTUs (6,711,804 kwh) nominal energy savings over the 49-year productive life of this component and 9,590,544,355 BTUs (2,810,828 kwh) real energy savings (**Table 29**). These estimates associated with the on-farm delivery-site meters are 8,739,428,083 BTUs (2,561,380 kwh) nominal energy savings over the 10-year productive life of this component and 6,815,825,995 BTUs (1,997,604 kwh) real energy savings (**Table 39**). For the total project, nominal energy savings are 41,595,212,685 BTUs (12,190,860 kwh) (**Tables 9**, **19**, **29**, and **39**) and real 2002 savings are 22,990,415,520 BTUs (6,738,105 kwh) (**Table 50**). On an average, annual, real basis, this amounts to **2,097,060,355 BTUs (614,613 kwh)** totaled across the four components (**Table 50)**.

Economic and financial cost of water savings forthcoming from the canal meters and telemetry equipment are estimated at $87.60 per ac-ft (**Table 9; Table 49**). Sensitivity analyses indicate these estimates can be affected by variances in (a) the amount of reduction in Rio Grande River diversions that will result from the purchase, installation, and implementation of the canal meters and telemetry equipment in the canal delivery system; (b) the expected useful life of the canal meters and telemetry equipment; (c) the initial capital investment costs of the canal meters and telemetry equipment; and (d) the value of BTU savings (i.e., cost of energy). Similar measures with regards to cost of energy savings associated with the canal meters and telemetry equipment are $0.0006466 per BTU ($2.206 per kwh) (**Table 9; Table 50**). Sensitivity analyses of these energy cost savings indicate factors of importance are (a) the amount of energy savings that will result from the purchase, installation, and implementation of the canal meters and telemetry equipment; (b) the expected useful life of the investment; (c) the initial capital investment costs; and (d) the percent off-farm water savings.

Economic and financial costs of water savings forthcoming from the impervious-lined delivery canals are estimated at $29.17 per ac-ft (**Table 19; Table 49**). Sensitivity analyses indicate these estimates can be affected by variances in (a) the amount of reduction in Rio Grande River diversions that will result from the purchase, installation, and implementation of the impervious-lined delivery canals in the canal delivery system; (b) the expected useful life of the impervious-lined delivery canals; (c) the initial capital investment costs of the impervious-lined delivery canals; and (d) the value of BTU savings (i.e., cost of energy). Similar measures with regards to cost of energy savings associated with the impervious-lined delivery canals are \$0.0001824 per BTU (\$0.622 per kwh) (**Table 19; Table 50**). Sensitivity analyses of these energy cost savings indicate factors of importance are (a) the amount of energy savings that will result from the purchase, installation, and implementation of the impervious-lined delivery canals; (b) the expected useful life of the investment; (c) the initial capital investment costs; and (d) the amount of off-farm and related on-farm water savings.

Economic and financial costs of water savings forthcoming from the 24" pipelines are estimated at \$13.20 per ac-ft (**Table 29; Table 49**). Sensitivity analyses indicate these estimates can be affected by variances in (a) the amount of reduction in Rio Grande River diversions that will result from the purchase, installation, and implementation of the 24" pipelines in the canal delivery system; (b) the expected useful life of the 24" pipelines; (c) the initial capital investment costs of the 24" pipelines; and (d) the value of BTU savings (i.e., cost of energy). Similar measures with regards to cost of energy savings associated with the 24" pipelines are \$0.0000982 per BTU (\$0.335 per kwh) (**Table 29; Table 50**). Sensitivity analyses of these energy cost savings indicate factors of importance are (a) the amount of energy savings that will result from the purchase, installation, and implementation of the 24" pipelines; (b) the expected useful life of the investment; (c) the initial capital investment costs; and (d) the amount of off-farm and related on-farm water savings.

Economic and financial costs of water savings forthcoming from the on-farm delivery-site meters are estimated at \$21.71 per ac-ft (**Table 39; Table 49**). Sensitivity analyses indicate these estimates can be affected by variances in (a) the amount of reduction in Rio Grande River diversions that will result from the purchase, installation, and implementation of the on-farm delivery-site meters in the canal delivery system; (b) the expected useful life of the on-farm delivery-site meters; (c) the initial capital investment costs of the on-farm delivery-site meters; and (d) the value of BTU savings (i.e., cost of energy). Similar measures with regards to cost of energy savings associated with the on-farm delivery-site meters are \$0.0001823 per BTU (\$0.622 per kwh) (**Table 39; Table 50**). Sensitivity analyses of these energy cost savings indicate factors of importance are (a) the amount of energy savings resulting from the purchase, installation, and implementation of the on-farm delivery-site meters; (b) the expected useful life of the investment; (c) the initial capital investment costs; and (d) on-farm water savings.

Aggregation of the economic and financial costs of water and energy savings for the individual project components into cost measures for the total comprehensive project result in estimates of **\$31.37 per ac-ft** cost of water savings (**Table 49**) and **\$0.0002253 per BTU (\$0.769 per kwh)** cost of energy savings (**Table 50**). These estimates, similar to the other economic and financial cost estimates identified here, are based on methods described in Rister et al. (2002).

References

Agrawal, R. C., and E. O Heady. Operations Research Methods for Agricultural Decisions. Ames, Iowa: The Iowa State University Press. 1972.

AWBLAIR ENGINEERING. *Harlingen Irrigation District Cameron County No. 1 TWDB Contract 2002-484001 Project Plan.* Dripping Springs, TX. April 15, 2002; amended July 14, 2002.

Blair, Al. Professional engineer, Dripping Springs, TX. Personal communications, Summer 2001-Fall 2002.

Border Environment Cooperative Commission. *Project Strategic Plan – Water Conservation Improvements for Harlingen Irrigation District Cameron County No. 1*. Juarez, Mexico. Project ID# 385, September 30, 2002.

Bureau of Reclamation. *Guidelines for Preparing and Reviewing Proposals for Water Conservation and Improvement Projects Under Public Law 106-576 – Lower Rio Grande Valley Water Resources Conservation and Improvement Act of 2000.* United States Department of Interior. June 2001.

Carpenter, George. Manager, Hidalgo Irrigation District No. 1, Edinburg, TX. Personal communications, Summer 2001-Fall 2002.

Clark, Rick, Mike Irlbeck, Bob Hamilton, Thomas Michalewicz, and Larry Walkoviak of the Bureau of Reclamation; Nick Palacios, Danny Fox, and Debbie Helstrom of the Texas Water Development Board; and Ron Lacewell and Ed Rister of the Texas Agricultural Experiment Station. Meeting at the Bureau's Oklahoma-Texas area office, Austin, TX. April 9, 2002a.

Clark, Rick, Mike Irlbeck, Thomas Michalewicz, and James Allard of the Bureau of Reclamation; Nick Palacios, Danny Fox, and Debbie Helstrom of the Texas Water Development Board; Megan Stubbs of the Governor's Office; Allan Jones of the Texas Water Resources Institute; and Ron Lacewell and Ed Rister of the Texas Agricultural Experiment Station. Meeting at the Bureau's Oklahoma-Texas area office, Austin, TX. July, 2002b.

Fipps, Guy. Agricultural Engineer, Texas Cooperative Extension, College Station, TX. Personal communications, Summer 2001-Fall 2002.

Fipps, Guy. "Potential Water Savings in Irrigated Agriculture for the Rio Grande Planning Region (Region M), Final Report." Department of Biological & Agricultural Engineering, Texas A&M University, College Station, TX. December 22, 2000. In Regional Water Supply Plan for the Rio Grande Regional Water Planning Area (Region M), Volume II, Technical Appendix, Technical Memorandum.

Fipps, Guy, Eric Leigh, Yanbo Huang, and David Flahive. http://idea.tamu.edu/ Texas Cooperative Extension, Department of Biological and Agricultural Engineering, Texas A&M University, College Station, TX. 2002.

Griffin, Ronald C. Professor of Natural Resource Economics, Department of Agricultural Economics, Texas A&M University. College Station, Texas. Personal communications, Spring - Summer 2002.

Griffin, Ronald C., and Manzoor E. Chowdhury. "Evaluating a Locally Financed Reservoir: The Case of Applewhite." *Journal of Water Resources Planning and Management*. 119,6(1993):628-44.

Halbert, Wayne. Manager, Harlingen Irrigation District Cameron County No. 1, Harlingen, TX. Personal communications, Summer 2001-Fall 2002.

Hamilton, Bob. Economist, Bureau of Reclamation, Denver, CO. Personal communications, Spring - Summer 2002.

Harlingen Irrigation District Cameron County No. 1. *A Step 1 Pre-Proposal for Environmental Infrastructure Projects Submitted to the Border Environment Cooperation Commission for a Grant for the Purchase and Installation of a District Wide Flow Measurement, Telemetry, and Water Delivery Management System.* Harlingen, Texas. August 23, 2002a.

Harlingen Irrigation District Cameron County No. 1. *A Step 1 Pre-Proposal for Environmental Infrastructure Projects Submitted to the Border Environment Cooperation Commission for a Grant for the Salvage of Water Lost to Seepage using Impervious Lining of Water Delivery Canals and Replacement of Existing Canals with Pipelines.* Harlingen, Texas. August 23, 2002b.

Infoplease.com. "Conversion Factors." © 2002 Family Education Network. http://www.infoplease.com/ipa/A0001729.html Date retrieved: August 1, 2002.

Kaniger, Sonia. Manager, Cameron Irrigation District # 2, San Benito, TX. Personal communications, Summer 2001-Fall 2002.

Klinefelter, Danny. Professor and Extension Economist, Agricultural Finance and Management Development, Texas A&M University, College Station, TX. Personal communications, Summer 2002.

Lewis, M.R., and W.E. Milne. "Analysis of Border Irrigation." *Agricultural Engineering*. June, 1938:267-272.

MapQuest. http://www.mapquest.com/. 2002.

Penson, Jr., John B. Regents Professor and Stiles Professor of Agriculture, Department of Agricultural Economics, Texas A&M University, College Station, TX. Spring - Summer 2002.

Rio Grande Regional Water Planning Group (Region M). *Regional Water Supply Plan for the Rio Grande Regional Water Planning Area (Region M), Vols. I and II.* Lower Rio Grande Valley Development Council and Texas Water Development Board. January 2001.

Rister, M. Edward, and Ronald D. Lacewell. "Researcher's Report: Economists Analyze Irrigation District Improvement Projects." *Rio Grande Basin Initiative Outcomes.* Texas Water Resources Institute. College Station, TX. Summer 2002, Vol. 1, No. 1, pp. 4, 8.

Rister, M. Edward, Ronald D. Lacewell, John R. Robinson, John R. Ellis, and Allen W. Sturdivant. "Economic Methodology for South Texas Irrigation Projects – RGIDECON©." Texas Water Resources Institute. TR-203. College Station, TX. October 2002.

Rister, M. Edward, Edward G. Smith, Victor M. Aguilar, David P. Anderson, and Ronald D. Lacewell. "An Economic Evaluation of Sugarcane Production and Processing in Southeast Texas." Environmental Issues/Sustainability DET 99-01, Texas Agricultural Experiment Station and Texas Agricultural Extension Service, Texas A&M University System. College Station, Texas. May 1999.

Shaddix, Shirley. Former project manager, United States of the Interior, Bureau of Reclamation, Great Plains Region, Oklahoma Office, Oklahoma City, OK. Personal correspondence, March 20, 2002.

Texas Natural Resource Conservation Commission. "Chapter 303: Operation of the Rio Grande;" 31 Texas Administrative Code, §§ 303.1-303.73; Texas Water Commission Rules; August 26, 1987; Austin, Texas.

United States Public Law 106-576. "Lower Rio Grande Valley Water Resources Conservation and Improvement Act of 2000." Enacted December, 28, 2000. Located on web site http://idea.tamu.edu/USPL106.doc, July 4, 2002.

Walkenbach, John. *Excel 97 Bible.* Southlake, TX: IDG Books Worldwide. 1996. pp. 570-7

Walkoviak, Larry. Area Manager, United States of the Interior, Bureau of Reclamation, Great Plains Region, Oklahoma - Texas Area Office, Austin, TX. Personal correspondence, July 24, 2002.

Glossary

Annuity equivalents: Expression of investment costs (from project components with differing life spans) in relation to water (or energy) savings expressed on an annualized basis into perpetuity. As used in this document and related analyses, a form of a common denominator used to establish calculated measures for capital investments of unequal useful lives on a common basis so that such measures may be compared across investment alternatives as well as combined into an aggregate measure when two or more components comprise a total proposed project.

BTU: British Thermal Unit, a standard measure of energy equal to 0.0002931 kilowatts; or, 3,412 BTU equals 1 kilowatt.

Canal lining: The lining of a dirt canal with concrete and/or combination of concrete and synthetic plastic material, to prevent seepage (i.e., impervious) and increase flow rates.

Capital budgeting analysis: Financial analysis method involving the discounting of future cash flow streams into a consistent, present-day, real value, facilitating comparison of capital investment projects having different length of planning horizons (i.e., years) and/or involving uneven annual cost streams.

Charged system: The condition when canals have enough water in them to facilitate the flow of water to a designated delivery point.

Component: One independent capital investment aspect of a District's total proposed capital renovation project.

Delivery system: The total system of pumping stations and canals used to deliver water within an irrigation district.

Diversion points: Point along a canal where end users appropriate irrigation water, using either pumping or gravity flow through a permanent valve apparatus.

DMI Reserve: Domestic, municipal, and industrial surplus reserves held in the Falcon and Amistad reservoirs per Allocation and Distribution of Waters policy (Texas Natural Resource Conservation Commission).

Drip/Micro emitter systems: Irrigation systems used in horticultural systems which, relative to furrow irrigation, use smaller quantities of water at higher frequencies.

Flood irrigation: Most common form of irrigation in the RGV region whereby individual rows or paddies are flooded through gravity flow.

Geographic Information System (GIS): Spatial information systems involving extensive, satellite-guided mapping associated with computer database overlays.

Head: Standard unit of measure of the flow rate of water; represents 3 cubic feet per second (Carpenter; Fipps 2001-2002).

Lateral: Smaller canals which branch off from main canals, and serve to deliver water to end users.

Lock system: A system to lift water in a canal to higher elevations via separate floodable chambers.

M&I: Municipal and industrial sources of water demand.

Mains: Larger canals which serve to deliver water from pumping stations to and across an irrigation district.

Nominal basis: Refers to non-inflation adjusted dollar values.

O&M: Operations and maintenance activities that represent variable costs.

Off-farm savings: Conserved units of water or energy that otherwise would have been expended in the irrigation district, i.e., during pumping or conveyance through canals.

On-farm savings: Conserved units of water or energy that otherwise would have been expended at the farm level.

Percolation losses: Losses of water in a crop field during irrigation due to seepage into the ground, below the root zone.

Polypipe: A flexible, hose-like plastic tubing used to convey water from field diversion points directly to the field.

Pro forma: Refers to projected financial statements or other performance measures.

Proration: Water allocation procedure in which a quantity of water that is smaller than that authorized by collective water rights is distributed proportionally among water rights holders.

Push water: Water filling a District's delivery system to provide for minimal delivery losses to be incurred as water is transported from the river-side diversion point to users' diversion points throughout the delivery system.

Real values: Numeric amounts which are expressed in time- and sometimes inflation-adjusted terms.

Relift pumping: Secondary pumping of water to enable continued gravity flow through a canal system.

Sensitivity analyses: Method of analysis to examine outcomes over a range of values for a given parameter.

Telemetry: Involving a wireless means of data transfer.

Turnout: Refers to the yield of water received by the end user at the diversion point.

Volumetric pricing: Method of pricing irrigations based on the precise quantity of water used, as opposed to pricing on a per-acre or per-irrigation basis.

Exhibits

Figure 1.

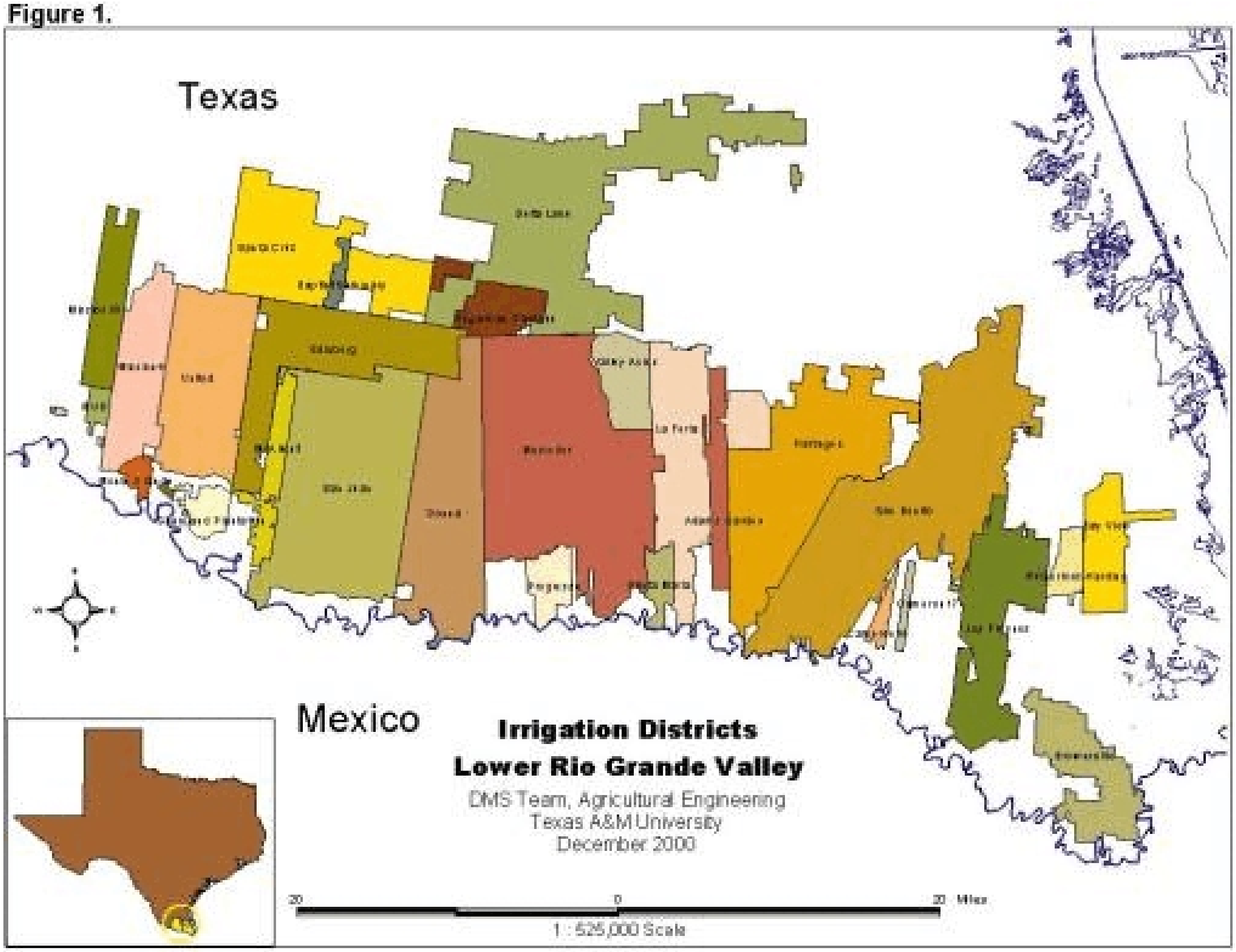

Exhibit 1. Graphic Illustration of Twenty-Eight Irrigation Districts in the Texas Lower Rio Grande Valley (Fipps et al.).

Exhibit 2. Harlingen, Texas – Location of Harlingen Irrigation District Cameron County No. 1 Office (MapQuest).

Exhibit 3. Detailed location of Harlingen Irrigation District Cameron County No. 1 Office in Harlingen, TX (MapQuest).

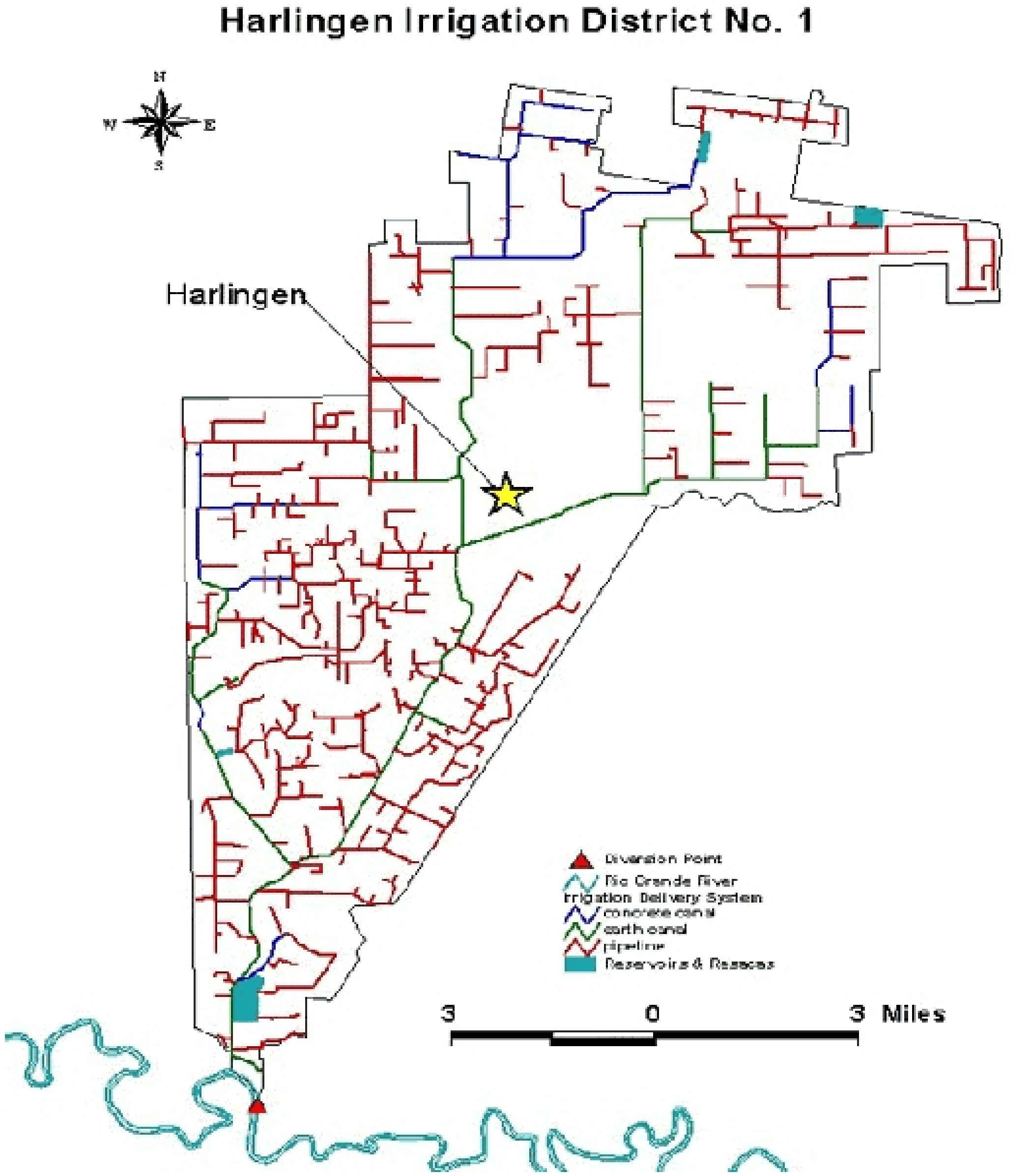

Exhibit 4. Illustrated Layout of Harlingen Irrigation District Cameron County No. 1 (Fipps et al.).

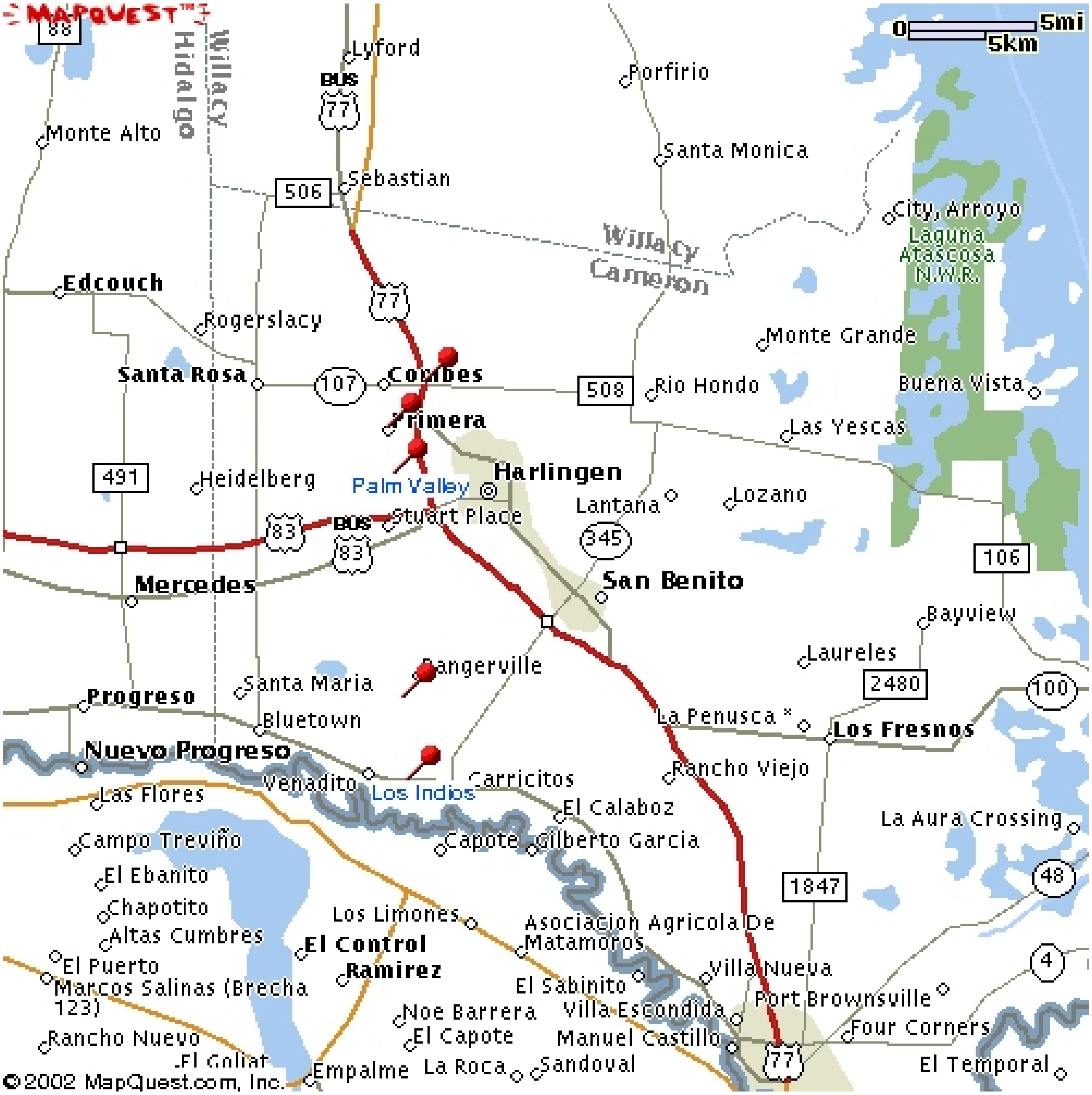

Exhibit 5. Location of Municipalities Served by Harlingen Irrigation District Cameron County No. 1, in Addition to Harlingen (MapQuest).

Tables

Table 1. Typical Irrigated Acreage in Harlingen Irrigation District Cameron County No. 1.[a]

Crop	Acres	%		Crop	Acres	%
Grain sorghum	10,850	31.22		**Nursery/trees/Plants**	400	1.15
Cotton	10,000	28.78		**Cabbage**	400	1.15
Sugar cane	7,000	20.14		**Other vegetables**	300	0.86
Pasture	1,800	5.18		**Aloe Vera**	200	0.58
Food corn	1,000	2.88		**Cucumbers**	125	0.36
Seed corn	750	2.16		**Green onions**	100	0.29
Citrus	600	1.73		**Squash**	75	0.22
Onions	600	1.73		**Peppers**	50	0.14
Feed corn	500	1.44				
				Totals	**34,750**	**100**

[a] These acreage statistics assembled from materials previously prepared by the Harlingen Irrigation District Cameron County No. 1 (Halbert).

Table 2. Historic Water Use Levels (acre-feet), Harlingen Irrigation District Cameron County No. 1, 1997-2001.

Use	1997	1998	1999	2000	2001	5 year (1997-2001) average
Ag	39,911	51,004	37,221	51,685	48,273	**45,619**
M&I	20,829	22,156	22,040	22,641	21,243	**21,782**
Total	**60,740**	**73,160**	**59,261**	**74,326**	**69,516**	**67,401**

Table 3. Summary of NADBank Project Data, Harlingen Irrigation District Cameron County No. 1, Canal Meters and Telemetry Equipment Component of Project, 2002.

Item	Description			Sub-Total	Total
Meters	105 meters located at 70 pumping sites and canal division points within the District's delivery system				
Installation Period					One year
Productive Period					Fifteen years
Planning Period					Sixteen years
Initial Capital Investment Costs	Meters			$747,538	
	Computer hardware for Management Information System			10,000	$757,538
Annual Increases in O&M Expenses	Digital telephone service, cash replacement of broken parts and batteries, etc.			$84,675	
	Two part-time office personnel			30,000	$114,675
Annual Water Savings	Off-Farm – Ag irrigation	45, 619 ac-ft	3%	1,368.6 ac-ft	
	Off-farm – M&I use	21,782 ac-ft	3%	653.5 ac-ft	2,022.1 ac-ft

Table 3, continued.

Item	Description	Water Savings	Energy Savings – BTUs	Energy Savings – kwh	Monetary Value of Energy Savings
Annual Energy Savings	Ag irrigation	1,368.6 ac-ft	194,209,513 BTUs	56,920 kwh	$5,692
	M&I	653.5 ac-ft	92,730,032 BTUs	27,178 kwh	$2,718
	total	2,022.1 ac-ft	286,939,545 BTUs	84,098 kwh	$10,410
Annual decreases in O&M Expenses					none
Value of Reclaimed Property					none

Table 4. Calculations Documenting Energy Use for Harlingen Irrigation District, 2001 Numbers (Halbert).

Item	Cost/Factor
Dollars spent	$289,122.00
2001 Irrigation water use (ac-ft)	48,273
2001 M&I water use (ac-ft)	21,243
2001 Total water use (ac-ft)	69,516
Assume energy cost is $0.10/kwh	$0.10
2001 Energy use (kwh)	2,891,220
2001 Energy use (kwh/ac-ft)	41.59
Conversion factor (BTU per kwh)	3,412
2001 Energy use (BTU/ac-ft)	**141,907.5**
Cost per BTU if 1 kwh costs $0.10	$0.0000293
2001 Energy costs ($/ac-ft)	$ 4.16

Table 5. Summary of NADBank Project Data, Harlingen Irrigation District Cameron County No. 1, Impervious-Lining of Delivery Canals Component of Project, 2002.

Item	Description			Sub-Total	Total
Impervious-Lining of Delivery Canals	3.26 miles of what are now concrete-lined laterals; Bowman A and Wyrick A, B, & C segments				
Installation Period					One year
Productive Period					Twenty years
Planning Period					Twenty-one years
Initial Capital Investment Costs	Impervious-Lining of Delivery Canals				$696,565
Annual Increases in O&M Expenses	Maintenance of impervious-lined delivery canals		3.26 miles	$400/mile	$1,304
Annual Water Savings	Off-Farm – Ag irrigation	3.26 miles	215.33 ac-ft/mi	701.9 ac-ft	
	On-Farm – Ag irrigation	3.26 miles	215.33 ac-ft/mi	701.9 ac-ft	1,403.7 ac-ft

Table 5, continued.

Item	Description	Water Savings	Energy Savings – BTUs	Energy Savings – kwh	Monetary Value of Energy Savings
Annual Energy Savings	Off-Farm – Ag irrigation	701.9 ac-ft	99,599,435 BTUs	29,191 kwh	$2,919
	On-Farm – Ag irrigation	701.9 ac-ft	99,599,435 BTUs	29,191 kwh	$2,919
	Off-Farm – Reduced relift pumping	492.6 ac-ft	69,897,092 BTUs	20,486 kwh	$2,049
	total	1,896.4 ac-ft	269,095,962 BTUs	78,868 kwh	$7,887
Annual decreases in O&M Expenses	Maintenance of concrete-lined delivery canals		3.26 miles	$1,600/mile	$5,215
Value of Reclaimed Property					none

Table 6. Current Concrete-Lined Delivery Canals Proposed for Conversion to Either Impervious-Lining or Pipeline, Harlingen Irrigation District Cameron County No. 1, NADBank Project, 2002.

Current Concrete-lined Delivery Canal Segments	canal width (ft)	pipeline diameter (in)	length (ft)	length (mi)	area (sq ft)
conversion to impervious-lined canal					
Bowman A	23.5		2,000	0.38	47,000
Wyrick A	15		9,500	1.8	142,500
Wyrick B	15		2,280	0.43	34,200
Wyrick C	15		3,430	0.65	51,450
total			17,210	3.26	275,150
conversion to pipeline					
Wyrick D		24	5,240	0.99	
Wyrick E		24	5,240	0.99	
Wyrick F		24	2,610	0.49	
Taylor A		24	10,300	1.95	
Citrus A		24	2,600	0.49	
Citrus B		24	3,900	0.74	
total			29,890	5.66	

Table 7. Summary of NADBank Project Data, Harlingen Irrigation District Cameron County No. 1, 24" Pipelines Replacing Delivery Canals Component of Project, 2002.

Item	Description			Sub-Total	Total
Pipelines Replacing Delivery Canals	5.66 miles of 24" pipelines replacing what are now concrete-lined laterals; Wyrick D, E, & F, Taylor A, and Citrus A & B segments				
Installation Period					One year
Productive Period					Forty-nine years
Planning Period					Fifty years
Initial Capital Investment Costs	24" Pipelines				$1,106,080
Annual Increases in O&M Expenses	Maintenance of pipelines		5.66 miles	$200/mile	$1,132
Annual Water Savings	Off-Farm – Ag irrigation	5.66 miles	215.33 ac-ft/mi	1,219.0 ac-ft	
	On-Farm – Ag irrigation	5.66 miles	215.33 ac-ft/mi	1,219.0 ac-ft	2,438.0 ac-ft

Table 7, continued.

Item	Description	Water Savings	Energy Savings – BTUs	Energy Savings – kwh	Monetary Value of Energy Savings
Annual Energy Savings	Off-Farm – Ag irrigation	1,219.0 ac-ft	172,982,401 BTUs	50,698 kwh	$5,070
	On-Farm – Ag irrigation	1,219.0 ac-ft	172,982,401 BTUs	50,698 kwh	$5,070
	Off-Farm – Reduced relift pumping	855.5 ac-ft	121,395,938 BTUs	35,579 kwh	$3,558
	total	3,293.1 ac-ft	467,360,740 BTUs	136,975 kwh	$13,698
Annual decreases in O&M Expenses	Maintenance of concrete-lined delivery canals		5.66 miles	$1,600/mile	$9,058
Value of Reclaimed Property					none

Table 8. Summary of NADBank Project Data, Harlingen Irrigation District Cameron County No. 1, On-Farm Delivery-Site Meters Component of Project, 2002.

Item	Description			Sub-Total	Total
Farm Delivery-Site Meters	400 meters located at farm delivery points				
Installation Period					One year
Productive Period					Ten years
Planning Period					Eleven years
Initial Capital Investment Costs	Farm Delivery-Site Meters				$649,816
Annual Increases in O&M Expenses	Maintenance of automatic meter readers				$76,000
Annual Water Savings	On-Farm – Ag irrigation	27%	50%	45,619 ac-ft	6,158.5 ac-ft
Annual Energy Savings	Ag irrigation	6,158.5 ac-ft	873,942,808 BTUs	256,138 kwh	$25,614
Annual decreases in O&M Expenses					none
Value of Reclaimed Property					none

Table 9. Economic and Financial Evaluation Results, Harlingen Irrigation District Cameron County No. 1, Canal Meters and Telemetry Equipment Component of NADBank Project, 2002.

Results		**Nominal**	**Real**
Water Savings (ac-ft)	Ag irrigation	20,528	14,631
	M&I	9,802	6,986
	Total	30,330	21,617
Energy Savings (BTUs)	Ag irrigation	2,913,142,694	2,076,246,739
	M&I	1,390,950,475	991,354,249
	Total	4,304,093,170	3,067,600,987
Energy Savings (kwh)	Ag irrigation	853,793	608,513
	M&I	407,664	290,549
	Total	1,261,457	899,062
NPV of Initial Capital Investment Costs and Changes in O&M Expenditures, Including Energy Cost Savings		$2,677,086	$1,893,594
Cost of Water Savings ($/ac-ft)			$87.60
NPV of Initial Capital Investment Costs and Changes in O&M Expenditures, Ignoring Both Energy Cost Savings and Value of Water Savings		$2,828,997	$1,983,501
Cost of Energy Savings ($/BTU)			$0.0006466
Cost of Energy Savings ($/kwh)			$2.206

Table 10. Costs per Acre-Foot of Water-Saved Sensitivity Analyses – Reduction in Rio Grande River Diversions Due to Off-Farm Savings and Expected Useful Life of the Capital Investment, Harlingen Irrigation District Cameron County No. 1, Canal Meters and Telemetry Equipment Project Component of NADBank Project, 2002.

		% reduction in RG diversions due to improved canal management									
		0.5%	1.0%	1.5%	2.0%	2.5%	**3.0%**	3.5%	4.0%	5.0%	10.0%
Expected Useful life of Investment (years)	5	1364.5855	677.09911	447.93699	333.35593	264.6073	218.77487	186.03743	161.48434	127.11003	58.36139
	8	902.29055	447.71115	296.18468	220.42145	174.96351	144.65822	123.01158	106.7766	84.047631	38.58969
	10	748.97918	371.63897	245.8589	182.96886	145.23484	120.07883	102.11025	88.633812	69.766802	32.03278
	11	693.44309	344.0823	227.6287	169.4019	134.46582	111.1751	94.538871	82.0617	64.59366	29.65758
	14	575.10379	285.36305	188.7828	140.49267	111.5186	92.20255	78.405372	68.057488	53.570451	24.59638
	15	546.38248	271.1117	179.35478	133.47632	105.94924	**87.597853**	74.489721	64.658622	50.895084	23.36801

Table 11. Costs per Acre-Foot of Water-Saved Sensitivity Analyses – Reduction in Rio Grande River Diversions Due to Off-Farm Savings and Initial Cost of the Capital Investment, Harlingen Irrigation District Cameron County No. 1, Canal Meters and Telemetry Equipment Project Component of NADBank Project, 2002.

		% reduction in RG diversions due to improved canal management									
		0.5%	1.0%	1.5%	2.0%	2.5%	**3.0%**	3.5%	4.0%	5.0%	10.0%
Initial Capital Investment Cost ($)	$-200,000	490.8704	243.3556	160.8507	119.5983	94.84682	78.34583	66.55942	57.71961	45.34387	20.5924
	$-100,000	518.6264	257.2337	170.1028	126.5373	100.398	82.97184	70.52457	61.18912	48.11948	21.9802
	$-50,000	532.5044	264.1727	174.7288	130.0068	103.1736	85.28485	72.50715	62.92387	49.50728	22.6741
	$ 0	546.3825	271.1117	179.3548	133.4763	105.9492	**87.59785**	74.48972	64.65862	50.89508	23.36801
	$50,000	560.2605	278.0507	183.9808	136.9458	108.7248	89.91086	76.4723	66.39338	52.28289	24.06191
	$100,000	574.1385	284.9897	188.6068	140.4153	111.5005	92.22386	78.45487	68.12813	53.67069	24.75581
	$200,000	601.8946	298.8678	197.8588	147.3543	117.0517	96.84987	82.42002	71.59764	56.44629	26.14

Table 12. Costs per Acre-Foot of Water-Saved Sensitivity Analyses – Reduction in Rio Grande River Diversions Due to Off-Farm Savings and Value of Energy Savings, Harlingen Irrigation District Cameron County No. 1, Canal Meters and Telemetry Equipment Project Component of NADBank Project, 2002.

	% reduction in RG diversions due to improved canal management										
		0.5%	1.0%	1.5%	2.0%	2.5%	**3.0%**	3.5%	4.0%	5.0%	10.0%
Value of Energy Savings ($/kwh)	$0.080	547.2143	271.9435	180.1866	134.3081	106.7811	88.42967	75.32154	65.49044	51.7269	24.19982
	$0.090	546.7984	271.5276	179.7707	133.8922	106.3651	88.01376	74.90563	65.07453	51.31099	23.78391
	$0.095	546.5904	271.3197	179.5627	133.6843	106.1572	87.80581	74.69767	64.86658	51.10304	23.57596
	$0.100	546.3825	271.1117	179.3548	133.4763	105.9492	**87.59785**	74.48972	64.65862	50.89508	23.36801
	$0.105	546.1745	270.9037	179.1468	133.2684	105.7413	87.3899	74.28177	64.45067	50.68713	23.16005
	$0.110	545.9666	270.6958	178.9389	133.0604	105.5333	87.18195	74.07381	64.24272	50.47918	22.9521
	$0.120	545.5507	270.2799	178.523	132.6445	105.1174	86.76604	73.65791	63.82681	50.06327	22.53619

Table 13. Costs per BTU of Energy-Saved Sensitivity Analyses – BTU of Energy Saved per Acre-Foot of Water Savings and Expected Useful Life of the Capital Investment, Harlingen Irrigation District Cameron County No. 1, Canal Meters and Telemetry Equipment Project Component of NADBank Project, 2002.

		variation in BTUs of all energy saved per ac-ft of water saved									
		80.0%	90.0%	95.0%	97.5%	**100.0%**	102.5%	105.0%	110.0%	125.0%	150.0%
		BTU of energy saved per ac-ft of water savings									
		113,526	127,716	134,812	138,359	**141,907.5**	145,455	149,002	156,098	177,384	212,861
Expected Useful life of Investment (years)	5	0.0020186	0.0017943	0.0016999	0.0016563	0.0016149	0.0015755	0.001538	0.0014681	0.0012919	0.001077
	8	0.0013347	0.0011864	0.001124	0.0010952	0.0010678	0.0010417	0.0010169	0.000971	0.000854	0.00071
	10	0.0011079	0.000985	0.000933	0.000909	0.000886	0.000865	0.000844	0.000806	0.000709	0.00059
	11	0.0010258	0.000912	0.000864	0.000842	0.000821	0.000801	0.000782	0.000746	0.000657	0.00055
	14	0.000851	0.000756	0.000716	0.000698	0.000681	0.000664	0.000648	0.000619	0.000544	0.00045
	15	0.000808	0.000718	0.000681	0.000663	**0.00064660**	0.000631	0.000616	0.000588	0.000517	0.00043

Table 14. Costs per kwh of Energy-Saved Sensitivity Analyses – BTU of Energy Saved per Acre-Foot of Water Savings and Expected Useful Life of the Capital Investment, Harlingen Irrigation District Cameron County No. 1, Canal Meters and Telemetry Equipment Project Component of NADBank Project, 2002.

		variation in BTUs of all energy saved per ac-ft of water saved									
		80.0%	90.0%	95.0%	97.5%	**100.0%**	102.5%	105.0%	110.0%	125.0%	150.0%
		BTU of energy saved per ac-ft of water savings									
		113,526	127,716	134,812	138,359	**141,907.5**	145,455	149,002	156,098	177,384	212,861
Expected Useful life of Investment (years)	5	6.887	6.12215	5.799932	5.651215	5.509935	5.375546	5.247557	5.009032	4.407948	3.67329
	8	4.554096	4.048085	3.835028	3.736694	3.643277	3.554416	3.469787	3.31207	2.914621	2.42885
	10	3.780293	3.360261	3.183405	3.101779	3.024235	2.950473	2.880223	2.749304	2.419388	2.01616
	11	3.499988	3.111101	2.947358	2.871785	2.79999	2.731698	2.666658	2.545446	2.239992	1.86666
	14	2.902699	2.580177	2.444378	2.381702	2.322159	2.265521	2.21158	2.111054	1.857727	1.54811
	15	2.757735	2.45132	2.322303	2.262757	**2.206188**	2.152378	2.101131	2.005625	1.76495	1.47079

Table 15. Costs per BTU of Energy-Saved Sensitivity Analyses – BTU of Energy Saved per Acre-Foot of Water Savings and Initial Cost of the Capital Investment, Harlingen Irrigation District Cameron County No. 1, Canal Meters and Telemetry Equipment Project Component of NADBank Project, 2002.

		variation in BTUs of all energy saved per ac-ft of water saved									
		80.0%	90.0%	95.0%	97.5%	**100.0%**	102.5%	105.0%	110.0%	125.0%	150.0%
		BTU of energy saved per ac-ft of water savings									
		113,526	127,716	134,812	138,359	**141,907.5**	145,455	149,002	156,098	177,384	212,861
Initial Capital Investment Cost ($)	$-200,000	0.000727	0.000646	0.000612	0.000596	0.000581	0.000567	0.000554	0.000529	0.000465	0.000388
	$-100,000	0.000768	0.000682	0.000646	0.00063	0.000614	0.000599	0.000585	0.000558	0.000491	0.000409
	$-50,000	0.000788	0.0007	0.000663	0.000646	0.00063	0.000615	0.0006	0.000573	0.000504	0.00042
	$-	0.000808	0.000718	0.000681	0.000663	**0.000647**	0.000631	0.000616	0.000588	0.000517	0.000431
	$50,000	0.000829	0.000737	0.000698	0.00068	0.000663	0.000647	0.000631	0.000603	0.00053	0.000442
	$100,000	0.000849	0.000755	0.000715	0.000697	0.000679	0.000663	0.000647	0.000617	0.000543	0.000453
	$200,000	0.00089	0.00079088	0.000749	0.00073	0.000712	0.000694	0.000678	0.000647	0.000569	0.000475

Table 16. Costs per kwh of Energy-Saved Sensitivity Analyses – BTU of Energy Saved per Acre-Foot of Water Savings and Initial Cost of the Capital Investment, Harlingen Irrigation District Cameron County No. 1, Canal Meters and Telemetry Equipment Project Component of NADBank Project, 2002.

		variation in BTUs of all energy saved per ac-ft of water saved									
		80.0%	90.0%	95.0%	97.5%	**100.0%**	102.5%	105.0%	110.0%	125.0%	150.0%
		BTU of energy saved per ac-ft of water savings									
		113,526	127,716	134,812	138,359	**141,907.5**	145,455	149,002	156,098	177,384	212,861
Initial Capital Investment Cost ($)	$-200,000	2.480	2.204149	2.088141	2.034599	1.983734	1.93535	1.88927	1.803394	1.586987	1.322489
	$-100,000	2.618701	2.327734	2.205222	2.148678	2.094961	2.043864	1.995201	1.90451	1.675969	1.396641
	$-50,000	2.688218	2.389527	2.263763	2.205717	2.150574	2.098121	2.048166	1.955068	1.72046	1.433716
	$-	2.757735	2.45132	2.322303	2.262757	**2.206188**	2.152378	2.101131	2.005625	1.76495	1.470792
	$50,000	2.827252	2.513113	2.380844	2.319796	2.261801	2.206635	2.154097	2.056183	1.809441	1.507868
	$100,000	2.896769	2.574905	2.439384	2.376836	2.317415	2.260893	2.207062	2.106741	1.853932	1.544943
	$200,000	3.035802	2.698491	2.556465	2.490915	2.428642	2.369407	2.312992	2.207856	1.942913	1.619095

Table 17. Costs per BTU of Energy-Saved Sensitivity Analyses – BTU of Energy Saved per Acre-Foot of Water Savings and Reduction in Rio Grande River Diversions Due to Off-Farm Savings, Harlingen Irrigation District Cameron County No. 1, Canal Meters and Telemetry Equipment Project Component of NADBank Project, 2002.

		variation in BTUs of all energy saved per ac-ft of water saved									
		80.0%	90.0%	95.0%	97.5%	**100.0%**	102.5%	105.0%	110.0%	125.0%	150.0%
		BTU of energy saved per ac-ft of water savings									
		113,526	127,716	134,812	138,359	**141,907.5**	145,455	149,002	156,098	177,384	212,861
% Water Savings of Current Use	0.50%	0.004849	0.0043106	0.0040838	0.0039791	0.0038796	0.003785	0.0036948	0.0035269	0.0031037	0.0025864
	1.00%	0.002425	0.0021553	0.0020419	0.0019895	0.0019398	0.0018925	0.0018474	0.0017634	0.0015518	0.0012932
	1.50%	0.001616	0.0014369	0.0013613	0.0013264	0.0012932	0.0012617	0.0012316	0.0011756	0.0010346	0.000862
	2.00%	0.001212	0.0010777	0.0010209	0.000995	0.00097	0.000946	0.000924	0.000882	0.000776	0.000647
	2.50%	0.00097	0.000862	0.000817	0.000796	0.000776	0.000757	0.000739	0.000705	0.000621	0.000517
	3.00%	0.00081	0.000718	0.000681	0.000663	**0.000647**	0.000631	0.000616	0.000588	0.000517	0.000431
	3.50%	0.00069	0.000616	0.000583	0.000568	0.000554	0.000541	0.000528	0.000504	0.000443	0.000369
	4.00%	0.00061	0.000539	0.00051	0.000497	0.000485	0.000473	0.000462	0.000441	0.000388	0.000323
	5.00%	0.00048	0.000431	0.000408	0.000398	0.000388	0.000379	0.000369	0.000353	0.00031	0.000259
	10.00%	0.00024	0.000216	0.000204	0.000199	0.000194	0.000189	0.000185	0.000176	0.000155	0.000129

Table 18. Costs per kwh of Energy-Saved Sensitivity Analyses – BTU of Energy Saved per Acre-Foot of Water Savings and Reduction in Rio Grande River Diversions Due to Off-Farm Savings, Harlingen Irrigation District Cameron County No. 1, Canal Meters and Telemetry Equipment Project Component of NADBank Project, 2002.

		variation in BTUs of all energy saved per ac-ft of water saved									
		80.0%	90.0%	95.0%	97.5%	**100.0%**	102.5%	105.0%	110.0%	125.0%	150.0%
		BTU of energy saved per ac-ft of water savings									
		113,526	127,716	134,812	138,359	**141,907.5**	145,455	149,002	156,098	177,384	212,861
% Water Savings of Current Use	0.50%	16.546	17.708	13.934	13.577	13.237	12.914	12.607	12.034	10.590	8.825
	1.00%	8.27320451	7.35395956	6.96690906	6.78827037	6.61856361	6.45713523	6.30339391	6.01687601	5.29485088	4.4123757
	1.50%	5.51546967	4.90263971	4.64460604	4.52551358	4.41237574	4.30475682	4.20226261	4.01125067	3.52990059	2.9415838
	2.00%	4.13660225	3.67697978	3.48345453	3.39413518	3.3092818	3.22856761	3.15169696	3.008438	2.64742544	2.2061879
	2.50%	3.3092818	2.94158382	2.78676362	2.71530815	2.64742544	2.58285409	2.52135756	2.4067504	2.11794035	1.7649503
	3.00%	2.75773484	2.45131985	2.32230302	2.26275679	**2.20618787**	2.15237841	2.1011313	2.00562534	1.76495029	1.4707919
	3.50%	2.36377272	2.1011313	1.99054545	1.93950582	1.89101817	1.84489578	1.80096969	1.71910743	1.51281454	1.2606788
	4.00%	2.06830113	1.83848989	1.74172726	1.69706759	1.6546409	1.61428381	1.57584848	1.504219	1.32371272	1.1030939
	5.00%	1.6546409	1.47079191	1.39338181	1.35765407	1.32371272	1.29142705	1.26067878	1.2033752	1.05897018	0.8824751
	10.00%	0.82732045	0.73539596	0.69669091	0.67882704	0.66185636	0.64571352	0.63033939	0.6016876	0.52948509	0.4412376

Table 19. Economic and Financial Evaluation Results, Harlingen Irrigation District Cameron County No. 1, Impervious-Lining of Delivery Canals Component of NADBank Project, 2002.

Results		Nominal	Real
Water Savings (ac-ft)	Ag irrigation	29,478	18,343
	M&I	0	0
	Total	29,478	18,343
Energy Savings (BTUs)	Ag irrigation	5,651,015,213	3,516,444,182
	M&I	0	0
	Total	5,651,015,213	3,516,444,182
Energy Savings (kwh)	Ag irrigation	1,656,218	1,030,611
	M&I	0	0
	Total	1,656,218	1,030,611
NPV of Initial Capital Investment Costs and Changes in O&M Expenditures, Including Energy Cost Savings		$ 375,624	$ 535,048
Cost of Water Savings ($/ac-ft)			$ 29.17
NPV of Initial Capital Investment Costs and Changes in O&M Expenditures, Ignoring Both Energy Cost Savings and Value of Water Savings		$ 588,331	$ 641,437
Cost of Energy Savings ($/BTU)			$ 0.0001824
Cost of Energy Savings ($/kwh)			$ 0.622

Table 20. Costs per Acre-Foot of Water-Saved Sensitivity Analyses – Water Savings per Mile of Impervious-Lined Canal and Expected Useful Life of the Capital Investment, Harlingen Irrigation District Cameron County No. 1, Impervious-Lining of Delivery Canals Project Component of NADBank Project, 2002.

	ac-ft of water savings per mile of impervious-lined canal										
		50	75	100	125	150	175	200	**215.33**	225	300
Expected Useful life of Investment (years)	5	426.81773	280.17628	206.85556	162.86313	133.53484	112.58606	96.874478	89.044589	84.654357	60.21412
	10	234.26718	153.78018	113.53668	89.390584	73.293184	61.795041	53.171434	48.873848	46.464185	33.04968
	12	202.46156	132.902	98.122213	77.254343	63.34243	53.405349	45.952538	42.23842	40.155908	28.56265
	15	170.89859	112.18309	82.825338	65.210689	53.46759	45.079661	38.788715	35.653614	33.895757	24.10984
	18	150.09654	98.527985	72.743708	57.273141	46.95943	39.592494	34.067292	31.3138	29.769912	21.17515
	20	139.81391	91.778151	67.760271	53.349544	43.742392	36.88014	31.733452	**29.168592**	27.730472	19.72451

Table 21. Costs per Acre-Foot of Water-Saved Sensitivity Analyses – Water Savings per Mile of Impervious-Lined Canal and Initial Cost of the Capital Investment, Harlingen Irrigation District Cameron County No. 1, Impervious-Lining of Delivery Canals Project Component of NADBank Project, 2002.

	ac-ft of water savings per mile of impervious-lined canal										
		50	75	100	125	150	175	200	**215.33**	225	300
Initial Capital Investment Cost ($)	$-200,000	92.85841	60.47448	44.28252	34.56734	28.09056	23.46428	19.99458	18.26544	17.29592	11.89859
	$-100,000	116.3362	76.12632	56.0214	43.95844	35.91647	30.17221	25.86401	23.71702	22.51319	15.81155
	$-50,000	128.075	83.95223	61.89083	48.65399	39.82943	33.52618	28.79873	26.4428	25.12183	17.76803
	$ 0	139.8139	91.77815	67.76027	53.34954	43.74239	36.88014	31.73345	**29.16859**	27.73047	19.72451
	$50,000	151.5528	99.60407	73.62971	58.04509	47.65535	40.2341	34.66817	31.89438	30.33911	21.68099
	$100,000	163.2917	107.43	79.49915	62.74064	51.56831	43.58807	37.60289	34.62017	32.94775	23.63747
	$200,000	186.7694	123.0818	91.23802	72.13174	59.39423	50.296	43.47233	40.07174	38.16503	27.55

Table 22. Costs per Acre-Foot of Water-Saved Sensitivity Analyses – Water Savings per Mile of Impervious-Lined Canal and Value of Energy Savings, Harlingen Irrigation District Cameron County No. 1, Impervious-Lining of Delivery Canals Project Component of NADBank Project, 2002.

	ac-ft of water savings per mile of impervious-lined canal										
		50	75	100	125	150	175	200	**215.33**	225	300
Value of Energy Savings ($/kwh)	0.08	141.9702	93.50188	69.26774	54.72725	45.03359	38.10955	32.91652	30.32857	28.8775	20.79945
	$0.090	140.892	92.64002	68.514	54.0384	44.38799	37.49485	32.32499	29.74858	28.30398	20.26198
	$0.095	140.353	92.20908	68.13714	53.69397	44.06519	37.18749	32.02922	29.45859	28.01723	19.99325
	$0.100	139.8139	91.77815	67.76027	53.34954	43.74239	36.88014	31.73345	**29.16859**	27.73047	19.72451
	$0.105	139.2748	91.34722	67.38341	53.00512	43.41959	36.57279	31.43768	28.8786	27.44372	19.45578
	$0.110	138.7358	90.91629	67.00654	52.66069	43.09679	36.26543	31.14192	28.58861	27.15696	19.18704
	$0.120	137.6577	90.05442	66.25281	51.97184	42.45119	35.65073	30.55038	28.00862	26.58345	18.64957

Table 23. Costs per BTU of Energy-Saved Sensitivity Analyses – BTU of Energy Saved per Acre-Foot of Water Savings and Expected Useful Life of the Capital Investment, Harlingen Irrigation District Cameron County No. 1, Impervious-Lining of Delivery Canals Project Component of NADBank Project, 2002.

		variation in BTUs of all energy saved per ac-ft of water saved									
		80.0%	90.0%	95.0%	97.5%	**100.0%**	102.5%	105.0%	110.0%	125.0%	150.0%
		BTU of energy saved per ac-ft of water savings									
		113,526	127,716	134,812	138,359	**141,907.5**	145,455	149,002	156,098	177,384	212,861
Expected Useful life of Investment (years)	5	0.000696	0.000619	0.000586	0.000571	0.000557	0.000543	0.00053	0.000506	0.000445	0.00037
	10	0.000382	0.00034	0.000322	0.000313	0.000306	0.000298	0.000291	0.000278	0.000245	0.0002
	12	0.00033	0.000293	0.000278	0.000271	0.000264	0.000258	0.000252	0.00024	0.000211	0.00018
	15	0.000279	0.000248	0.000235	0.000229	0.000223	0.000218	0.000212	0.000203	0.000178	0.00015
	18	0.000245	0.000218	0.000206	0.000201	0.000196	0.000191	0.000187	0.000178	0.000157	0.00013
	20	0.000228	0.000203	0.000192	0.00018709	**0.000182**	0.000178	0.000174	0.000166	0.000146	0.00012

Table 24. Costs per kwh of Energy-Saved Sensitivity Analyses – BTU of Energy Saved per Acre-Foot of Water Savings and Expected Useful Life of the Capital Investment, Harlingen Irrigation District Cameron County No. 1, Impervious-Lining of Delivery Canals Project Component of NADBank Project, 2002.

		variation in BTUs of all energy saved per ac-ft of water saved									
		80.0%	90.0%	95.0%	97.5%	**100.0%**	102.5%	105.0%	110.0%	125.0%	150.0%
		BTU of energy saved per ac-ft of water savings									
		113,526	127,716	134,812	138,359	**141,907.5**	145,455	149,002	156,098	177,384	212,861
Expected Useful life of Investment (years)	5	2.375	2.1111031	1.9999925	1.9487106	1.8999928	1.8536515	1.809517	1.7272662	1.5199943	1.266662
	10	1.3035599	1.1587199	1.0977346	1.0695876	1.0428479	1.0174126	0.9931885	0.9480435	0.8342783	0.695232
	12	1.1265802	1.0014046	0.9486991	0.9243735	0.9012641	0.8792821	0.8583468	0.819331	0.7210113	0.600843
	15	0.9509507	0.8452895	0.8008006	0.7802672	0.7607605	0.7422054	0.7245339	0.6916005	0.6086084	0.507174
	18	0.8351995	0.7423995	0.7033259	0.6852919	0.6681596	0.651863	0.6363425	0.6074178	0.5345277	0.44544
	20	0.7779827	0.6915401	0.6551433	0.6383447	**0.6223861**	0.607206	0.5927487	0.5658056	0.4979089	0.414924

Table 25. Costs per BTU of Energy-Saved Sensitivity Analyses – BTU of Energy Saved per Acre-Foot of Water Savings and Initial Cost of the Capital Investment, Harlingen Irrigation District Cameron County No. 1, Impervious-Lining of Delivery Canals Project Component of NADBank Project, 2002.

		variation in BTUs of all energy saved per ac-ft of water saved									
		80.0%	90.0%	95.0%	97.5%	**100.0%**	102.5%	105.0%	110.0%	125.0%	150.0%
		BTU of energy saved per ac-ft of water savings									
		113,526	127,716	134,812	138,359	**141,907.5**	145,455	149,002	156,098	177,384	212,861
Initial Capital Investment Cost ($)	$-200,000	0.00016	0.00014	0.00013	0.00013	0.00013	0.00012	0.00012	0.00011	0.0001	0.00008
	$-100,000	0.00019	0.00017	0.00016	0.00016	0.00015	0.00015	0.00015	0.00014	0.00012	0.000103
	$-50,000	0.00021	0.00019	0.00018	0.00017	0.00017	0.00016	0.00016	0.00015	0.00013	0.000112
	$-	0.00023	0.0002	0.00019	0.00019	**0.00018**	0.00018	0.00017	0.00017	0.00015	0.000122
	$500,000	0.00025	0.00022	0.00021	0.0002	0.0002	0.00019	0.00019	0.00018	0.00016	0.000131
	$100,000	0.00026	0.00023	0.00022	0.00022	0.00021	0.00021	0.0002	0.00019	0.00017	0.000141
	$200,000	0.00029911	0.00027	0.00025	0.00025	0.00024	0.00023	0.00023	0.00022	0.00019	0.00016

Table 26. Costs per kwh of Energy-Saved Sensitivity Analyses – BTU of Energy Saved per Acre-Foot of Water Savings and Initial Cost of the Capital Investment, Harlingen Irrigation District Cameron County No. 1, Impervious-Lining of Delivery Canals Project Component of NADBank Project, 2002.

		variation in BTUs of all energy saved per ac-ft of water saved									
		80.0%	90.0%	95.0%	97.5%	**100.0%**	102.5%	105.0%	110.0%	125.0%	150.0%
		BTU of energy saved per ac-ft of water savings									
		113,526	127,716	134,812	138,359	**141,907.5**	145,455	149,002	156,098	177,384	212,861
Initial Capital Investment Cost ($)	$-200,000	0.535	0.475918	0.45087	0.439309	0.428326	0.417879	0.40793	0.389388	0.342661	0.285551
	$-100,000	0.656695	0.583729	0.553007	0.538827	0.525356	0.512543	0.500339	0.477597	0.420285	0.350238
	$-50,000	0.717339	0.637635	0.604075	0.588586	0.573871	0.559874	0.546544	0.521701	0.459097	0.382581
	$-	0.777983	0.69154	0.655143	0.638345	**0.622386**	0.607206	0.592749	0.565806	0.497909	0.414924
	$500,000	0.838626	0.745446	0.706212	0.688104	0.670901	0.654538	0.638953	0.60991	0.536721	0.447267
	$100,000	0.89927	0.799351	0.75728	0.737863	0.719416	0.701869	0.685158	0.654015	0.575533	0.479611
	$200,000	1.020557	0.907162	0.859417	0.83738	0.816446	0.796532	0.777567	0.742223	0.653157	0.544297

Table 27. Costs per BTU of Energy-Saved Sensitivity Analyses – BTU of Energy Saved per Acre-Foot of Water Savings and Reduction in Rio Grande River Diversions Due to Off- and On-Farm Savings, Harlingen Irrigation District Cameron County No. 1, Impervious-Lining of Delivery Canals Project Component of NADBank Project, 2002.

		variation in BTUs of all energy saved per ac-ft of water saved									
		80.0%	90.0%	95.0%	97.5%	**100.0%**	102.5%	105.0%	110.0%	125.0%	150.0%
		BTU of energy saved per ac-ft of water savings									
		113,526	127,716	134,812	138,359	**141,907.5**	145,455	149,002	156,098	177,384	212,861
Off-Farm Ac-Ft of Water Savings per Mile of Impervious-Lined Canal	50	0.00053	0.00047	0.000445	0.000433	0.000423	0.000412	0.000402	0.000384	0.000338	0.000282
	75	0.00044	0.000392	0.000371	0.000361	0.000352	0.000344	0.000336	0.00032	0.000282	0.000235
	100	0.00038	0.000336	0.000318	0.00031	0.000302	0.000295	0.000288	0.000275	0.000242	0.000202
	125	0.00033	0.000294	0.000278	0.000271	0.000265	0.000258	0.000252	0.000241	0.000212	0.000176
	150	0.00029	0.000261	0.000248	0.000241	0.000235	0.00023	0.000224	0.000214	0.000188	0.000157
	175	0.00026	0.000235	0.000223	0.000217	0.000212	0.000207	0.000202	0.000193	0.000169	0.000141
	200	0.00024	0.000214	0.000203	0.000198	0.000193	0.000188	0.000183	0.000175	0.000154	0.000128
	215.33	0.00023	0.000203	0.000192	0.000187	**0.000182**	0.000178	0.000174	0.000166	0.000146	0.000122
	225	0.00022	0.000196	0.000186	0.000181	0.000177	0.000172	0.000168	0.00016	0.000141	0.000118
	300	0.00018	0.000157	0.000149	0.000145	0.000141	0.000138	0.000135	0.000128	0.000113	0.00009

Table 28. Costs per kwh of Energy-Saved Sensitivity Analyses – BTU of Energy Saved per Acre-Foot of Water Savings and Reduction in Rio Grande River Diversions Due to Off- and On-Farm Savings, Harlingen Irrigation District Cameron County No. 1, Impervious-Lining of Delivery Canals Project Component of NADBank Project, 2002.

		variation in BTUs of all energy saved per ac-ft of water saved									
		80.0%	90.0%	95.0%	97.5%	**100.0%**	102.5%	105.0%	110.0%	125.0%	150.0%
		BTU of energy saved per ac-ft of water savings									
		113,526	127,716	134,812	138,359	**141,907.5**	145,455	149,002	156,098	177,384	212,861
Off-Farm Ac-Ft of Water Savings per Mile of Impervious-Lined Canal	50	1.802	1.602	1.518	1.479	1.442	1.407	1.373	1.311	1.154	0.961
	75	1.50311695	1.33610395	1.26578269	1.23332673	1.20249356	1.17316445	1.14523196	1.09317596	0.96199485	0.8016624
	100	1.28906768	1.14583794	1.08553068	1.05769656	1.03125415	1.00610161	0.98214681	0.93750377	0.82500332	0.6875028
	125	1.12838202	1.00300624	0.95021644	0.92585192	0.90270562	0.88068841	0.85971964	0.82064147	0.72216449	0.6018037
	150	1.00331605	0.89183649	0.84489773	0.82323368	0.80265284	0.78307594	0.76443128	0.7296844	0.64212227	0.5351019
	175	0.90320763	0.80285123	0.7605959	0.74109344	0.72256611	0.70494254	0.6881582	0.65687828	0.57805288	0.4817107
	200	0.82126393	0.73001238	0.69159068	0.67385758	0.65701114	0.64098648	0.6257249	0.59728286	0.52560891	0.4380074
	215.33	0.77798265	0.69154014	0.65514329	0.63834474	**0.62238612**	0.60720597	0.59274869	0.56580557	0.4979089	0.4149241
	225	0.75295218	0.66929083	0.63406499	0.61780692	0.60236175	0.58767	0.57367785	0.54760159	0.4818894	0.4015745
	300	0.60258523	0.53563132	0.5074402	0.49442891	0.48206819	0.47031043	0.45911256	0.43824381	0.38565455	0.3213788

Table 29. Economic and Financial Evaluation Results, Harlingen Irrigation District Cameron County No. 1, 24" Pipelines Replacing Delivery Canals Component of NADBank Project, 2002.

Results		Nominal	Real
Water Savings (ac-ft)	Ag irrigation	119,460	50,029
	M&I	0	0
	Total	119,460	50,029
Energy Savings (BTUs)	Ag irrigation	22,900,676,219	9,590,544,355
	M&I	0	0
	Total	22,900,676,219	9,590,544,355
Energy Savings (kwh)	Ag irrigation	6,711,804	2,810,828
	M&I	0	0
	Total	6,711,804	2,810,828
NPV of Initial Capital Investment Costs and Changes in O&M Expenditures, Including Energy Cost Savings		$ -763,236	$ 660,310
Cost of Water Savings ($/ac-ft)			$ 13.20
NPV of Initial Capital Investment Costs and Changes in O&M Expenditures, Ignoring Both Energy Cost Savings and Value of Water Savings		$ 419,417	$ 941,393
Cost of Energy Savings ($/BTU)			$0.0000982
Cost of Energy Savings ($/kwh)			$0.335

Table 30. Costs per Acre-Foot of Water-Saved Sensitivity Analyses – Water Savings per Mile of Pipelines and Expected Useful Life of the Capital Investment, Harlingen Irrigation District Cameron County No. 1, 24" Pipelines Replacing Delivery Canals Project Component of NADBank Project, 2002.

		ac-ft of water savings per mile of pipelines									
		50	75	100	125	150	175	200	**215.33**	225	300
Expected Useful life of Investment (years)	10	185.74713	120.18362	87.401868	67.732816	54.620115	45.2539	38.229238	34.728489	32.765613	21.83836
	20	110.85647	71.727256	52.16265	40.423887	32.598044	27.008157	22.815741	20.726445	19.554973	13.03344
	25	96.43886	62.398658	45.378557	35.166496	28.358455	23.495569	19.848405	18.030835	17.011721	11.33835
	30	87.125415	56.372597	40.996187	31.770342	25.619778	21.226518	17.931574	16.289533	15.368839	10.24337
	40	76.117455	49.250137	35.816477	27.756282	22.382818	18.54463	15.665988	14.231414	13.427045	8.949159
	49	70.593799	45.676175	33.217364	25.742077	20.758552	17.198892	14.529146	**13.198675**	12.452678	8.29974

Table 31. Costs per Acre-Foot of Water-Saved Sensitivity Analyses – Water Savings per Mile of Pipelines and Initial Cost of the Capital Investment, Harlingen Irrigation District Cameron County No. 1, 24" Pipelines Replacing Delivery Canals Project Component of NADBank Project, 2002.

		ac-ft of water savings per mile of pipelines									
		50	75	100	125	150	175	200	**215.33**	225	300
Initial Capital Investment Cost ($)	$-500,000	27.55234	16.98187	11.69663	8.525493	6.411399	4.901332	3.768782	3.204374	2.887909	1.126164
	$-250,000	49.07307	31.32902	22.457	17.13379	13.58498	11.05011	9.148964	8.201524	7.670293	4.712952
	$-100,000	61.98551	39.93731	28.91322	22.29876	17.88912	14.73938	12.37707	11.19981	10.53972	6.865025
	$ -	70.5938	45.67618	33.21736	25.74208	20.75855	17.19889	14.52915	**13.19868**	12.45268	8.29974
	$100,000	79.20209	51.41504	37.52151	29.18539	23.62798	19.6584	16.68122	15.19754	14.36563	9.734456
	$250,000	92.11453	60.02333	43.97773	34.35037	27.93213	23.34767	19.90933	18.19583	17.23506	11.88653
	$500,000	113.6353	74.37048	54.73809	42.95866	35.1057	29.49645	25.28951	23.19298	22.01745	15.47332

Table 32. Costs per Acre-Foot of Water-Saved Sensitivity Analyses – Water Savings per Mile of Pipelines and Value of Energy Savings, Harlingen Irrigation District Cameron County No. 1, 24" Pipelines Replacing Delivery Canals Project Component of NADBank Project, 2002.

	ac-ft of water savings per mile of pipelines										
		50	75	100	125	150	175	200	**215.33**	225	300
Value of Energy Savings ($/kwh)	$0.080	72.68261	47.34599	34.67767	27.07669	22.00936	18.38985	15.67521	14.32237	13.56382	9.341054
	$0.090	71.6382	46.51108	33.94752	26.40938	21.38396	17.79437	15.10218	13.76052	13.00825	8.820397
	$0.095	71.116	46.09363	33.58244	26.07573	21.07126	17.49663	14.81566	13.4796	12.73046	8.560069
	$0.100	70.5938	45.67618	33.21736	25.74208	20.75855	17.19889	14.52915	**13.19868**	12.45268	8.29974
	$0.105	70.0716	45.25872	32.85229	25.40842	20.44585	16.90115	14.24263	12.91775	12.17489	8.039412
	$0.110	69.54939	44.84127	32.48721	25.07477	20.13315	16.60341	13.95611	12.63683	11.8971	7.779084
	$0.120	68.50499	44.00637	31.75705	24.40747	19.50774	16.00794	13.38308	12.07498	11.34153	7.258427

Table 33. Costs per BTU of Energy-Saved Sensitivity Analyses – BTU of Energy Saved per Acre-Foot of Water Savings and Expected Useful Life of the Capital Investment, Harlingen Irrigation District Cameron County No. 1, 24" Pipelines Replacing Delivery Canals Project Component of NADBank Project, 2002.

		variation in BTUs of all energy saved per ac-ft of water saved									
		80.0%	90.0%	95.0%	97.5%	**100.0%**	102.5%	105.0%	110.0%	125.0%	150.0%
		BTU of energy saved per ac-ft of water savings									
		113,526	127,716	134,812	138,359	**141,907.5**	145,455	149,002	156,098	177,384	212,861
Expected Useful life of Investment (years)	10	0.000323	0.000287	0.000272	0.000265	0.000258	0.000252	0.000246	0.000235	0.000207	0.00017
	20	0.000193	0.000171	0.000162	0.000158	0.000154	0.00015	0.000147	0.00014	0.000123	0.0001
	25	0.000168	0.000149	0.000141	0.000138	0.000134	0.000131	0.000128	0.000122	0.000107	0.0001
	30	0.000151	0.000135	0.000128	0.000124	0.000121	0.000118	0.000115	0.00011	0.0001	0.0001
	40	0.000132	0.000118	0.000111	0.000109	0.000106	0.000103	0.000101	0.0001	0.00008	0.0001
	49	0.000123	0.000109	0.000103	0.000101	**0.0001**	0.0001	0.00009	0.00009	0.00008	0.0001

Table 34. Costs per kwh of Energy-Saved Sensitivity Analyses – BTU of Energy Saved per Acre-Foot of Water Savings and Expected Useful Life of the Capital Investment, Harlingen Irrigation District Cameron County No. 1, 24" Pipelines Replacing Delivery Canals Project Component of NADBank Project, 2002.

		variation in BTUs of all energy saved per ac-ft of water saved									
		80.0%	90.0%	95.0%	97.5%	**100.0%**	102.5%	105.0%	110.0%	125.0%	150.0%
		BTU of energy saved per ac-ft of water savings									
		113,526	127,716	134,812	138,359	**141,907.5**	145,455	149,002	156,098	177,384	212,861
Expected Useful life of Investment (years)	10	1.102	0.979151	0.9276168	0.9038317	0.8812359	0.8597424	0.8392723	0.8011236	0.7049887	0.587491
	20	0.6574173	0.584371	0.5536146	0.5394193	0.5259339	0.5131062	0.5008894	0.4781217	0.4207471	0.350623
	25	0.5719159	0.5083697	0.4816134	0.4692643	0.4575327	0.4463734	0.4357455	0.4159388	0.3660262	0.305022
	30	0.5166839	0.4592746	0.4351023	0.4239458	0.4133472	0.4032655	0.393664	0.3757701	0.3306777	0.275565
	40	0.4514029	0.401247	0.3801288	0.3703819	0.3611223	0.3523145	0.343926	0.328293	0.2888979	0.240748
	49	0.4186457	0.3721295	0.3525438	0.3435042	**0.3349166**	0.3267479	0.3189682	0.3044696	0.2679333	0.223278

Table 35. Costs per BTU of Energy-Saved Sensitivity Analyses – BTU of Energy Saved per Acre-Foot of Water Savings and Initial Cost of the Capital Investment, Harlingen Irrigation District Cameron County No. 1, 24" Pipelines Replacing Delivery Canals Project Component of NADBank Project, 2002.

		variation in BTUs of all energy saved per ac-ft of water saved									
		80.0%	90.0%	95.0%	97.5%	**100.0%**	102.5%	105.0%	110.0%	125.0%	150.0%
		BTU of energy saved per ac-ft of water savings									
		113,526	127,716	134,812	138,359	**141,907.5**	145,455	149,002	156,098	177,384	212,861
Initial Capital Investment Cost ($)	$-500,000	0.00006	0.00005	0.00005	0.00005	0.00005	0.00004	0.00004	0.00004	0.00004	0.00003
	$-250,000	0.00009	0.00008	0.00008	0.00007	0.00007	0.00007	0.00007	0.00007	0.00006	0.00005
	$-100,000	0.00011	0.0001	0.00009	0.00009	0.00009	0.00009	0.00008	0.00008	0.00007	0.00006
	$-	0.000123	0.000109	0.000103	0.000101	**0.0001**	0.0001	0.00009	0.00009	0.00008	0.00007
	$100,000	0.000136	0.000121	0.000114	0.000111	0.000109	0.000106	0.000103	0.0001	0.00009	0.00007
	$250,000	0.000155	0.000138	0.000131	0.000127	0.000124	0.000121	0.000118	0.000113	0.0001	0.00008
	$500,000	0.000188	0.000167	0.000158	0.000154	0.00015	0.000147	0.000143	0.000137	0.00012	0.0001

Table 36. Costs per kwh of Energy-Saved Sensitivity Analyses – BTU of Energy Saved per Acre-Foot of Water Savings and Initial Cost of the Capital Investment, Harlingen Irrigation District Cameron County No. 1, 24" Pipelines Replacing Delivery Canals Project Component of NADBank Project, 2002.

		variation in BTUs of all energy saved per ac-ft of water saved									
		80.0%	90.0%	95.0%	97.5%	**100.0%**	102.5%	105.0%	110.0%	125.0%	150.0%
		BTU of energy saved per ac-ft of water savings									
		113,526	127,716	134,812	138,359	**141,907.5**	145,455	149,002	156,098	177,384	212,861
Initial Capital Investment Cost ($)	$-500,000	0.196	0.174481	0.165298	0.16106	0.157033	0.153203	0.149555	0.142757	0.125626	0.104689
	$-250,000	0.307469	0.273305	0.258921	0.252282	0.245975	0.239975	0.234262	0.223613	0.19678	0.163983
	$-100,000	0.374175	0.3326	0.315095	0.307015	0.29934	0.292039	0.285086	0.272127	0.239472	0.19956
	$-	0.418646	0.37213	0.352544	0.343504	**0.334917**	0.326748	0.318968	0.30447	0.267933	0.223278
	$100,000	0.463117	0.411659	0.389993	0.379993	0.370493	0.361457	0.352851	0.336812	0.296395	0.246996
	$250,000	0.529823	0.470954	0.446167	0.434727	0.423858	0.41352	0.403675	0.385326	0.339087	0.282572
	$500,000	0.641	0.569778	0.53979	0.525949	0.5128	0.500293	0.488381	0.466182	0.41024	0.341867

Table 37. Costs per BTU of Energy-Saved Sensitivity Analyses – BTU of Energy Saved per Acre-Foot of Water Savings and Reduction in Rio Grande River Diversions Due to Off- and On-Farm Savings, Harlingen Irrigation District Cameron County No. 1, 24" Pipelines Replacing Delivery Canals Project Component of NADBank Project, 2002.

		variation in BTUs of all energy saved per ac-ft of water saved									
		80.0%	90.0%	95.0%	97.5%	**100.0%**	102.5%	105.0%	110.0%	125.0%	150.0%
		BTU of energy saved per ac-ft of water savings									
		113,526	127,716	134,812	138,359	**141,907.5**	145,455	149,002	156,098	177,384	212,861
Off-Farm Ac-Ft of Water Savings per Mile of Pipelines	50	0.00028	0.000253	0.000239	0.000233	0.000227	0.000222	0.000217	0.000207	0.000182	0.000152
	75	0.00024	0.000211	0.0002	0.000195	0.00019	0.000185	0.000181	0.000172	0.000152	0.000126
	100	0.0002	0.000181	0.000171	0.000167	0.000163	0.000159	0.000155	0.000148	0.00013	0.000108
	125	0.00018	0.000158	0.00015	0.000146	0.000142	0.000139	0.000136	0.000129	0.000114	0.00009
	150	0.00016	0.000141	0.000133	0.00013	0.000127	0.000124	0.000121	0.000115	0.000101	0.00008
	175	0.00014	0.000127	0.00012	0.000117	0.000114	0.000111	0.000109	0.000104	0.00009	0.00008
	200	0.00013	0.000115	0.000109	0.000106	0.000104	0.000101	0.0001	0.00009	0.00008	0.00007
	215.33	0.00012	0.000109	0.000103	0.000101	**0.0001**	0.0001	0.00009	0.00009	0.00008	0.00007
	225	0.00012	0.000106	0.0001	0.0001	0.0001	0.00009	0.00009	0.00009	0.00008	0.00006
	300	0.0001	0.00008	0.00008	0.00008	0.00008	0.00007	0.00007	0.00007	0.00006	0.00005

Table 38. Costs per kwh of Energy-Saved Sensitivity Analyses – BTU of Energy Saved per Acre-Foot of Water Savings and Reduction in Rio Grande River Diversions Due to Off- and On-Farm Savings, Harlingen Irrigation District Cameron County No. 1, 24" Pipelines Replacing Delivery Canals Project Component of NADBank Project, 2002.

		variation in BTUs of all energy saved per ac-ft of water saved									
		80.0%	90.0%	95.0%	97.5%	**100.0%**	102.5%	105.0%	110.0%	125.0%	150.0%
		BTU of energy saved per ac-ft of water savings									
		113,526	127,716	134,812	138,359	**141,907.5**	145,455	149,002	156,098	177,384	212,861
Off-Farm Ac-Ft of Water Savings per Mile of Pipelines	50	0.970	0.862	0.817	0.796	0.776	0.757	0.739	0.705	0.621	0.517
	75	0.80885285	0.71898031	0.68113924	0.66367413	0.64708228	0.63129978	0.61626884	0.58825662	0.51766582	0.4313882
	100	0.69366929	0.61659493	0.58414256	0.56916455	0.55493543	0.54140042	0.52850994	0.50448676	0.44394835	0.369957
	125	0.6072016	0.53973475	0.51132766	0.4982167	0.48576128	0.47391344	0.46262979	0.44160116	0.38860902	0.3238409
	150	0.53990147	0.47991242	0.45465387	0.44299608	0.43192117	0.42138651	0.4113535	0.39265561	0.34553694	0.2879474
	175	0.48603142	0.43202793	0.40928962	0.39879501	0.38882514	0.3793416	0.37030965	0.3534774	0.31106011	0.2592168
	200	0.44193612	0.3928321	0.37215673	0.36261425	0.35354889	0.34492575	0.33671323	0.32140809	0.28283912	0.2356993
	215.33	0.41864573	0.37212953	0.35254377	0.34350418	**0.33491658**	0.32674788	0.31896817	0.30446962	0.26793326	0.2232777
	225	0.4051764	0.3601568	0.34120118	0.33245243	0.32414112	0.31623524	0.30870583	0.29467375	0.2593129	0.2160941
	300	0.32426139	0.28823234	0.27306222	0.26606062	0.25940911	0.25308206	0.24705629	0.23582646	0.20752729	0.1729394

Table 39. Economic and Financial Evaluation Results, Harlingen Irrigation District Cameron County No. 1, On-Farm Delivery-Site Meters Component of NADBank Project, 2002.

Results		**Nominal**	**Real**
Water Savings (ac-ft)	Ag irrigation	61,585	48,030
	M&I	0	0
	Total	61,585	48,030
Energy Savings (BTUs)	Ag irrigation	8,739,428,083	6,815,825,996
	M&I	0	0
	Total	8,739,428,083	6,815,825,996
Energy Savings (kwh)	Ag irrigation	2,561,380	1,997,604
	M&I	0	0
	Total	2,561,380	1,997,604
NPV of Initial Capital Investment Costs and Changes in O&M Expenditures, Including Energy Cost Savings		$ 1,225,445	$ 1,042,775
Cost of Water Savings ($/ac-ft)			$21.71
NPV of Initial Capital Investment Costs and Changes in O&M Expenditures, Ignoring Both Energy Cost Savings and Value of Water Savings		$ 1,518,066	$ 1,242,535
Cost of Energy Savings ($/BTU)			$ 0.0001823
Cost of Energy Savings ($/kwh)			$ 0.622

Table 40. Costs per Acre-Foot of Water-Saved Sensitivity Analyses – Reductions in Rio Grande River Diversions and Expected Useful Life of the Capital Investment, Harlingen Irrigation District Cameron County No. 1, On-Farm Delivery-Site Meters Project Component of NADBank Project, 2002.

		percent reduction in Rio Grande River diversions (on 50% of irrigation water use)									
		1%	5%	10%	20%	25%	**27%**	30%	35%	40%	50%
Expected Useful life of Investment (years)	5	1265.018	246.94158	119.68203	56.052252	43.326296	39.555643	34.842326	28.782347	24.237363	17.87439
	6	1074.3015	209.7122	101.63854	47.601708	36.794341	33.592159	29.589431	24.443066	20.583292	15.17961
	7	938.28459	183.16062	88.770122	41.574874	32.135824	29.339069	25.843124	21.348339	17.97725	13.25772
	8	836.4546	163.28259	79.136093	37.062843	28.648193	26.154963	23.038426	19.03145	16.026218	11.81889
	9	757.4155	147.85353	71.658287	33.560664	25.941139	23.683502	20.861456	17.233111	14.511853	10.70209
	10	694.32965	135.53867	65.6898	30.765365	23.780477	**21.710881**	19.123886	15.80	13.303147	9.810703

Table 41. Costs per Acre-Foot of Water-Saved Sensitivity Analyses – Reductions in Rio Grande River Diversions and Initial Cost of the Capital Investment, Harlingen Irrigation District Cameron County No. 1, On-Farm Delivery-Site Meters Project Component of NADBank Project, 2002.

		percent reduction in Rio Grande River diversions (on 50% of irrigation water use)									
		1%	5%	10%	20%	25%	**27%**	30%	35%	40%	50%
Initial Capital Investment Cost ($)	$-200,000	581.90005	113.05275	54.446841	25.143885	19.28329	17.546822	15.376233	12.585475	10.492407	7.562111
	$-100,000	638.11485	124.29571	60.068321	27.954625	21.53189	19.628852	17.250059	14.191612	11.897777	8.686407
	$-50,000	666.22225	129.91719	62.87906	29.359995	22.65618	20.669866	18.186973	14.994681	12.600462	9.248555
	$ -	694.32965	135.53867	65.6898	30.765365	23.78048	**21.710881**	19.123886	15.797749	13.303147	9.810703
	$50,000	722.43704	141.16015	68.50054	32.170735	24.90477	22.751896	20.060799	16.600818	14.005832	10.37285
	$100,000	750.54444	146.78163	71.31128	33.576104	26.02907	23.792911	20.997713	17.403886	14.708517	10.935
	$200,000	806.75924	158.02459	76.93276	36.386844	28.27766	25.87494	22.871539	19.010023	16.113887	12.0593

Table 42. Costs per Acre-Foot of Water-Saved Sensitivity Analyses – Reductions in Rio Grande River Diversions and Value of Energy Savings, Harlingen Irrigation District Cameron County No. 1, On-Farm Delivery-Site Meters Project Component of NADBank Project, 2002.

		percent reduction in Rio Grande River diversions (on 50% of irrigation water use)									
		1%	5%	10%	20%	25%	**27%**	30%	35%	40%	50%
Value of Energy Savings ($/kwh)	$0.080	695.1615	136.3705	66.52161	31.59718	24.61229	22.5427	19.9557	16.62956	14.13496	10.64252
	$0.090	694.7456	135.9546	66.10571	31.18127	24.19638	22.12679	19.53979	16.21366	13.71905	10.22661
	$0.095	694.5376	135.7466	65.89775	30.97332	23.98843	21.91883	19.33184	16.0057	13.5111	10.01866
	$0.100	694.3296	135.5387	65.6898	30.76536	23.78048	**21.71088**	19.12389	15.79775	13.30315	9.810703
	$0.105	694.1217	135.3307	65.48185	30.55741	23.57252	21.50293	18.91593	15.5898	13.09519	9.602749
	$0.110	693.9137	135.1228	65.27389	30.34946	23.36457	21.29497	18.70798	15.38184	12.88724	9.394796
	$0.120	693.4978	134.7069	64.85799	29.93355	22.94866	20.87907	18.29207	14.96593	12.47133	8.978889

Table 43. Costs per BTU of Energy-Saved Sensitivity Analyses – BTU of Energy Saved per Acre-Foot of Water Savings and Expected Useful Life of the Capital Investment, Harlingen Irrigation District Cameron County No. 1, On-Farm Delivery-Site Meters Project Component of NADBank Project, 2002.

		variation in BTUs of all energy saved per ac-ft of water saved									
		80.0%	90.0%	95.0%	97.5%	**100.0%**	102.5%	105.0%	110.0%	125.0%	150.0%
		BTU of energy saved per ac-ft of water savings									
		113,526	127,716	134,812	138,359	**141,907.5**	145,455	149,002	156,098	177,384	212,861
Expected Useful life of Investment (years)	5	0.000415	0.000369	0.00035	0.000341	0.000332	0.000324	0.000316	0.000302	0.000266	0.00022
	6	0.000353	0.000313	0.000297	0.000289	0.000282	0.000275	0.000269	0.000256	0.000226	0.00019
	7	0.000308	0.000274	0.000259	0.000253	0.000246	0.00024	0.000235	0.000224	0.000197	0.00016
	8	0.000275	0.000244	0.000231	0.000225	0.00022	0.000214	0.000209	0.0002	0.000176	0.00015
	9	0.000249	0.000221	0.000209	0.000204	0.000199	0.000194	0.000189	0.000181	0.000159	0.00013
	10	0.000228	0.000203	0.000192	0.000187	**0.000182**	0.000178	0.000174	0.000166	0.000146	0.00012

Table 44. Costs per kwh of Energy-Saved Sensitivity Analyses – BTU of Energy Saved per Acre-Foot of Water Savings and Expected Useful Life of the Capital Investment, Harlingen Irrigation District Cameron County No. 1, On-Farm Delivery-Site Meters Project Component of NADBank Project, 2002.

		variation in BTUs of all energy saved per ac-ft of water saved									
		80.0%	90.0%	95.0%	97.5%	**100.0%**	102.5%	105.0%	110.0%	125.0%	150.0%
		BTU of energy saved per ac-ft of water savings									
		113,526	127,716	134,812	138,359	**141,907.5**	145,455	149,002	156,098	177,384	212,861
Expected Useful life of Investment (years)	5	1.417	1.2591798	1.1929072	1.1623199	1.1332619	1.1056213	1.079297	1.0302381	0.9066095	0.755508
	6	1.2030114	1.0693435	1.0130623	0.9870863	0.9624091	0.9389357	0.9165801	0.8749174	0.7699273	0.641606
	7	1.0506986	0.9339543	0.8847988	0.8621117	0.8405589	0.8200575	0.8005323	0.7641444	0.6724471	0.560373
	8	0.9366686	0.8325943	0.7887735	0.7685486	0.7493349	0.7310584	0.7136522	0.6812135	0.5994679	0.499557
	9	0.84816	0.75392	0.71424	0.6959261	0.678528	0.6619785	0.6462171	0.6168436	0.5428224	0.452352
	10	0.7775159	0.6911253	0.6547502	0.6379618	**0.6220127**	0.6068417	0.5923931	0.5654661	0.4976102	0.414675

Table 45. Costs per BTU of Energy-Saved Sensitivity Analyses – BTU of Energy Saved per Acre-Foot of Water Savings and Initial Cost of the Capital Investment, Harlingen Irrigation District Cameron County No. 1, On-Farm Delivery-Site Meters Project Component of NADBank Project, 2002.

		variation in BTUs of all energy saved per ac-ft of water saved									
		80.0%	90.0%	95.0%	97.5%	**100.0%**	102.5%	105.0%	110.0%	125.0%	150.0%
		BTU of energy saved per ac-ft of water savings									
		113,526	127,716	134,812	138,359	**141,907.5**	145,455	149,002	156,098	177,384	212,861
Initial Capital Investment Cost ($)	$-200,000	0.000191	0.00017	0.000161	0.000157	0.000153	0.000149	0.000146	0.000139	0.000122	0.000102
	$-100,000	0.00021	0.000186	0.000176	0.000172	0.000168	0.000164	0.00016	0.000152	0.000134	0.000112
	$-50,000	0.000219	0.000194	0.000184	0.000179	0.000175	0.000171	0.000167	0.000159	0.00014	0.000117
	$-	0.000228	0.000203	0.000192	0.000187	**0.000182**	0.000178	0.000174	0.000166	0.000146	0.000122
	$50,000	0.000237	0.000211	0.0002	0.000195	0.00019	0.000185	0.000181	0.000172	0.000152	0.000126
	$100,000	0.000246	0.000219	0.000207	0.000202	0.000197	0.000192	0.000188	0.000179	0.000158	0.000131
	$200,000	0.00026456	0.000235	0.000223	0.000217	0.000212	0.000206	0.000202	0.000192	0.000169	0.000141

Table 46. Costs per kwh of Energy-Saved Sensitivity Analyses – BTU of Energy Saved per Acre-Foot of Water Savings and Initial Cost of the Capital Investment, Harlingen Irrigation District Cameron County No. 1, On-Farm Delivery-Site Meters Project Component of NADBank Project, 2002.

		variation in BTUs of all energy saved per ac-ft of water saved									
		80.0%	90.0%	95.0%	97.5%	**100.0%**	102.5%	105.0%	110.0%	125.0%	150.0%
		BTU of energy saved per ac-ft of water savings									
		113,526	127,716	134,812	138,359	**141,907.5**	145,455	149,002	156,098	177,384	212,861
Initial Capital Investment Cost ($)	$-200,000	0.652	0.579881	0.549361	0.535275	0.521893	0.509164	0.497041	0.474448	0.417514	0.347929
	$-100,000	0.714941	0.635503	0.602056	0.586618	0.571953	0.558003	0.544717	0.519957	0.457562	0.381302
	$-50,000	0.746228	0.663314	0.628403	0.61229	0.596983	0.582422	0.568555	0.542712	0.477586	0.397989
	$-	0.777516	0.691125	0.65475	0.637962	**0.622013**	0.606842	0.592393	0.565466	0.49761	0.414675
	$50,000	0.808803	0.718936	0.681098	0.663634	0.647043	0.631261	0.616231	0.588221	0.517634	0.431362
	$100,000	0.840091	0.746747	0.707445	0.689305	0.672073	0.655681	0.640069	0.610975	0.537658	0.448048
	$200,000	0.902666	0.80237	0.76014	0.740649	0.722133	0.70452	0.687745	0.656484	0.577706	0.481422

Table 47. Costs per BTU of Energy-Saved Sensitivity Analyses – BTU of Energy Saved per Acre-Foot of Water Savings and Reduction in Rio Grande River Diversions Due to On-Farm Savings, Harlingen Irrigation District Cameron County No. 1, On-Farm Delivery-Site Meters Project Component of NADBank Project, 2002.

		variation in BTUs of all energy saved per ac-ft of water saved									
		80.0%	90.0%	95.0%	97.5%	**100.0%**	102.5%	105.0%	110.0%	125.0%	150.0%
		BTU of energy saved per ac-ft of water savings									
		113,526	127,716	134,812	138,359	**141,907.5**	145,455	149,002	156,098	177,384	212,861
% Water Savings of Current Farm Use on 50% of Ag Water	1.00%	0.006153	0.005469	0.0051812	0.0050483	0.0049221	0.0048021	0.0046878	0.0044747	0.0039377	0.0032814
	5.00%	0.001231	0.0010938	0.0010362	0.0010097	0.000984	0.00096	0.000938	0.000895	0.000788	0.000656
	10.00%	0.00062	0.000547	0.000518	0.000505	0.000492	0.00048	0.000469	0.000447	0.000394	0.000328
	20.00%	0.00031	0.000273	0.000259	0.000252	0.000246	0.00024	0.000234	0.000224	0.000197	0.000164
	25.00%	0.00025	0.000219	0.000207	0.000202	0.000197	0.000192	0.000188	0.000179	0.000158	0.000131
	27.00%	0.00023	0.000203	0.000192	0.000187	**0.000182**	0.000178	0.000174	0.000166	0.000146	0.000122
	30.00%	0.00021	0.000182	0.000173	0.000168	0.000164	0.00016	0.000156	0.000149	0.000131	0.000109
	35.00%	0.00018	0.000156	0.000148	0.000144	0.000141	0.000137	0.000134	0.000128	0.000113	0.00009
	40.00%	0.00015	0.000137	0.00013	0.000126	0.000123	0.00012	0.000117	0.000112	0.0001	0.00008
	50.00%	0.00012	0.000109	0.000104	0.000101	0.0001	0.0001	0.00009	0.00009	0.00008	0.00007

Table 48. Costs per kwh of Energy-Saved Sensitivity Analyses – BTU of Energy Saved per Acre-Foot of Water Savings and Reduction in Rio Grande River Diversions Due to On-Farm Savings, Harlingen Irrigation District Cameron County No. 1, On-Farm Delivery-Site Meters Project Component of NADBank Project, 2002.

		variation in BTUs of all energy saved per ac-ft of water saved									
		80.0%	90.0%	95.0%	97.5%	**100.0%**	102.5%	105.0%	110.0%	125.0%	150.0%
		BTU of energy saved per ac-ft of water savings									
		113,526	127,716	134,812	138,359	**141,907.5**	145,455	149,002	156,098	177,384	212,861
% Water Savings of Current Farm Use on 50% of Ag Water	1.00%	20.993	18.660	17.678	17.225	16.794	16.385	15.995	15.268	13.435	11.196
	5.00%	4.19858594	3.73207639	3.53565131	3.44499359	3.35886875	3.27694512	3.19892262	3.05351704	2.687095	2.2392458
	10.00%	2.09929297	1.86603819	1.76782566	1.72249679	1.67943437	1.63847256	1.59946131	1.52675852	1.3435475	1.1196229
	20.00%	1.04964648	0.9330191	0.88391283	0.8612484	0.83971719	0.81923628	0.79973065	0.76337926	0.67177375	0.5598115
	25.00%	0.83971719	0.74641528	0.70713026	0.68899872	0.67177375	0.65538902	0.63978452	0.61070341	0.537419	0.4478492
	27.00%	0.77751591	0.69112526	0.65475024	0.63796178	**0.62201273**	0.60684169	0.59239308	0.56546612	0.49761018	0.4146752
	30.00%	0.69976432	0.62201273	0.58927522	0.5741656	0.55981146	0.54615752	0.53315377	0.50891951	0.44784917	0.3732076
	35.00%	0.59979799	0.53315377	0.50509304	0.49214194	0.47983839	0.46813502	0.45698895	0.43621672	0.38387071	0.3198923
	40.00%	0.52482324	0.46650955	0.44195641	0.4306242	0.41985859	0.40961814	0.39986533	0.38168963	0.33588687	0.2799057
	50.00%	0.41985859	0.37320764	0.35356513	0.34449936	0.33588687	0.32769451	0.31989226	0.3053517	0.2687095	0.2239246

Table 49. Economic and Financial Evaluation Results for Cost of Water Saved, Aggregated Across Canal Meters and Telemetry Equipment, Impervious-Lining of Delivery Canals, 24" Pipelines Replacing Delivery Canals, and On-Farm Delivery-Site Meters, Harlingen Irrigation District Cameron County No. 1 NADBank Project, 2002.

Economic/Engineering Measures	**Project Component**				**Aggregate**
	Canal Meters and Telemetry Equipment	**Impervious-Lined Delivery Canals**	**24" Pipelines Replacing Delivery Canals**	**On-Farm Delivery-Site Meters**	
NPV of Net Cost Stream, Including Both Initial Investment Cost and Changes in O&M Expenditures ($)	$ 1,893,594	$ 535,049	$ 660,310	$ 1,042,775	$4,131,728
Annuity Equivalent of Net Cost Stream for Calculating of Annuity Equivalents ($/yr)	$ 188,987	$ 45,961	$ 42,626	$ 133,063	$ 410,637
NPV of All Water Savings (ac-ft)	21,617	18,343	50,029	48,030	138,019
Annuity Equivalent of All Water Savings Stream for Weighting of Annuity Equivalents (ac-ft/yr)	2,157	1,576	3,230	6,129	13,092
Annuity Equivalent of Costs per ac-ft of Water Savings, Assuming Perpetual Timeline and Replacement with Identical Technology	$ 87.60	$ 29.17	$ 13.20	$ 21.71	**$ 31.37**

Table 50. Economic and Financial Evaluation Results for Cost of Energy Saved, Aggregated Across Canal Meters and Telemetry Equipment, Impervious-Lining of Delivery Canals, Pipelines Replacing Delivery Canals, and On-Farm Delivery-Site Meters, Harlingen Irrigation District Cameron County No. 1 NADBank Project, 2002.

	Project Component				
Economic/Engineering Measures	**Canal Meters and Telemetry Equipment**	**Impervious-Lined Delivery Canals**	**24" Pipelines Replacing Delivery Canals**	**On-Farm Delivery-Site Meters**	**Aggregate**
NPV of Net Cost Stream, Including Both Initial Investment Cost and Changes in O&M Expenditures ($)	$ 1,983,501	$ 641,438	$ 941,393	$ 1,242,535	$4,808,867
Annuity Equivalent of Net Cost Stream for Calculating of Annuity Equivalents ($/yr)	$ 197,960	$ 55,100	$ 60,771	$ 158,553	$ 472,384
NPV of All Energy Savings (BTU)	3,067,600,987	3,516,444,182	9,590,544,355	6,815,825,996	22,990,415,520
Annuity Equivalent of All Energy Savings Stream for Weighting of Annuity Equivalents (BTU/yr)	306,156,742	302,063,807	619,107,843	869,731,963	2,097,060,356
Annuity Equivalent of All Energy Savings Stream for Weighting of Annuity Equivalents (kwh/yr)	89,729	88,530	181,450	254,904	614,613
Annuity Equivalent of Costs per BTU of Energy Savings, Assuming Perpetual Timeline and Replacement with Identical Technology ($)	$ 0.0006466	$ 0.0001824	$ 0.0000982	$ 0.0001823	$ 0.0002253
Annuity Equivalent of Costs per kwh of Energy Savings, Assuming Perpetual Timeline and Replacement with Identical Technology ($)	$ 2.206	$ 0.622	$ 0.335	$ 0.622	**$ 0.769**

Appendices

Appendix A: Legislated Criteria Results – By Component

Public Law 106-576 legislation requires three economic measures be calculated and included as part of the information prepared for the Bureau of Reclamation's evaluation of the proposed projects (Bureau of Reclamation):

- Number of ac-ft of water saved per dollar of construction costs;
- Number of BTU of energy saved per dollar of construction costs; and
- Dollars of annual economic savings per dollar of initial construction costs.

Discussions with Bob Hamilton of the Denver Bureau of Reclamation office on April 9, 2002 indicated these measures are often stated in an inverse mode, i.e.,

- Dollars of construction cost per ac-ft of water saved.
- Dollars of construction cost per BTU (and kwh) of energy saved.
- Dollars of construction cost per dollar of annual economic savings.

Hamilton's suggested convention is adopted and used in the RGIDECON© model section reporting the Public Law 106-576 legislation's required measures. It is on that basis that the legislated criteria results are presented in both Appendices A and B of this report. Appendix A is focused on results for the individual capital renovation components comprising the total proposed project. Aggregated results for the total project are presented in Appendix B.

The noted criteria involve a series of calculations similar to, but different than, those used in developing the cost measures cited in the main body of this report. Principal differences consist of the legislated criteria not requiring aggregation of the initial capital investment costs with the annual changes in O&M expenditures, but rather entailing separate sets of calculations for each type of costs relative to the anticipated water and energy savings. While the legislated criteria does not specify the need for discounting the nominal values into real terms, both nominal and real values are presented in Appendix A to account for the differences in length of planning periods across multiple components of a single project and across different projects. With regards to the annual economic savings referred to in the third criteria, these are summed into a single present value quantity inasmuch as the annual values may vary through the planning period. Only real results are presented in Appendix B since the aggregation of results requires combining of results for the different components, necessitating a common basis of evaluation. Readers are directed to Rister et al. (2002) for more information regarding the issues associated with comparing capital investments having differences in length of planning periods.

Component #1 -- Canal Meters and Telemetry Equipment

The 'Canal Meters and Telemetry Equipment' component of the District's project consists of installing 105 metering devices at 70 locations throughout the District's delivery system: (a) at each of the numerous pump sites where pressure is increased to operate pipelines; and (b) at canal division points. Details on the cost estimates and related projections of associated water and energy savings are presented in the main body of this report (**Tables 3** and **9**). A summary of the calculated values is presented in the next section, followed by a discussion of the results corresponding to the legislated criteria. Discounted, real transformations of those nominal values are also indicated.

Summary Values

Table A1 is a summary of the key calculated values used in determining the legislated criteria results appearing in **Table A2** for the 'Canal Meters and Telemetry Equipment' component of the District's NADBank project. These summary values are derived in RGIDECON©, using the several input parameters described in the main body of this report.

The 'Initial Construction Costs' are $757,538, with no difference between the nominal and real values (**Table A1**). These costs are those associated with the canal meters and telemetry equipment's purchase and installation, their integration into the management information system, and other implementation requirements. It is assumed all such costs occur on the first day of the planning period, thereby negating the need for any discounting of future capital investment costs and causing the nominal and real measures to be the same.

A total of 30,330 ac-ft of nominal off-farm water savings is projected to occur during the 15-year productive life of the canal meters and telemetry equipment. Using a 4% discount rate, the present or real value of such anticipated water savings is 21,617 ac-ft (**Table A1**).

A total of 4,304,093,170 BTUs (1,261,458 kwh) of nominal energy savings is presumed associated with the forecast off-farm water savings during the 15-year productive life of the canal meters and telemetry equipment. Using a 4% discount rate, the present or real value of such anticipated energy savings is 3,067,600,987 BTUs (899,062 kwh) (**Table A1**).

The accrued net changes in annual O&M expenditures over the 15-year productive life of the canal meters and telemetry equipment are a total increase of $1,919,548 in nominal terms. Using the 2002 Federal discount rate of 6.125%, this anticipated net increase in expenditures represents a real cost of $1,136,056 (**Table A1**).

Criteria Stated in Legislated Guidelines

The principal evaluation criteria specified in the Public Law 106-576 legislation, transformed according to Hamilton, are presented in **Table A2** for the 'Canal Meters and Telemetry Equipment' component of the District's NADBank project. These respective measures are calculated using the summary values reported in **Table A1.** Both nominal and real measures are presented.

The estimated costs of initial construction per ac-ft of water savings are $24.98 in a nominal sense and $35.04 in real terms (**Table A2**). The real estimates are higher than the nominal because of the discounting of future water savings in conjunction with all construction costs occurring at the onset of the project component.

The estimated costs of initial construction per BTU (kwh) of energy savings are $0.0001760 ($0.60) in a nominal sense and $0.0002470 ($0.84) in real terms (**Table A2**). The real estimates are higher than the nominal because of the discounting of future energy savings in conjunction with all construction costs occurring at the onset of the project component.

Consideration of the changes in both energy savings and other O&M expenditures forthcoming from the canal meters and telemetry equipment capital renovation result in anticipated net increases in annual costs (**Table A1**). Comparing the initial construction costs to those increases in operating costs provides for a ratio measure of 0.39 of construction costs per additional dollar of nominal operating expenditures, suggesting construction costs are less than the expected nominal increase in economic O&M costs. On a real basis, this ratio measure is 0.67 (**Table A2**), signifying construction costs are also less than the expected real increase in economic O&M costs, but by a lesser margin than inferred in the nominal calculations.

Component #2 -- Impervious-Lining of Delivery Canals

The 'Impervious-Lining of Delivery Canals' component of the District's project consists of installing 3.26 miles of impervious-lined delivery canals in place of what are now concrete-lined delivery canals. Details on the cost estimates and related projections of associated water and energy savings are presented in the main body of this report (**Tables 5** and **19**). A summary of the calculated values is presented in the next section, followed by a discussion of the results corresponding to the legislated criteria. Discounted, real transformations of those nominal values are also indicated.

<u>**Summary Values**</u>

Table A3 is a summary of the key calculated values used in determining the legislated criteria results appearing in **Table A4** for the 'Impervious-Lining of Delivery Canals' component of the District's NADBank project. These summary values are derived in RGIDECON© using the several input parameters described in the main body of this report.

The 'Initial Construction Costs' are $696,565, with no difference between the nominal and real values (**Table A3**). These costs are those associated with the impervious-lined delivery canals' purchase and installation, and other implementation requirements. It is assumed all such costs occur on the first day of the planning period, thereby negating the need for any discounting of future costs and causing the nominal and real measures to be the same.

A total of 29,478 ac-ft of nominal off- and on-farm water savings are projected to occur during the 20-year productive life of the impervious-lined delivery canals. Using a 4% discount rate, the present or real value of such anticipated water savings is 18,343 ac-ft (**Table A3**).

A total of 5,651,015,214 BTUs (1,656,218 kwh) of nominal energy savings is presumed associated with the forecast off- and on-farm water savings during the 20-year productive life of the impervious-lined delivery canals. Using a 4% discount rate, the present or real value of such anticipated savings is 3,516,444,182 BTUs (1,030,611 kwh) (**Table A3**).

The accrued annual net changes in O&M expenditures over the 20-year productive life of the impervious-lined delivery canals are a total decrease of $320,941 in nominal terms. Using the 2002 Federal discount rate of 6.125%, this anticipated net decrease in expenditures represents a real cost reduction of $161,516 (**Table A3**). As noted in the main body of the text, this anticipated net cost savings stems from substantial energy savings and no other anticipated changes in O&M expenditures.

Criteria Stated in Guidelines

The principal evaluation criteria specified in the Public Law 106-576 legislation, transformed according to Hamilton, are presented in **Table A4** for the 'impervious-lined delivery canals' component of the District's NADBank project. These respective measures are calculated using the summary values reported in **Table A3.** Both nominal and real measures are presented.

The estimated costs of initial construction per ac-ft of water savings are $23.63 in a nominal sense and $37.97 in real terms (**Table A4**). The real estimates are higher than the nominal because of the discounting of future water savings in conjunction with all construction costs occurring at the onset of the project component.

The estimated costs of initial construction per BTU (kwh) of energy savings are $0.0001233 ($0.42) in a nominal sense and $0.0001981 ($0.68) in real terms (**Table A4**). The real estimates are higher than the nominal because of the discounting of future energy savings in conjunction with all construction costs occurring at the onset of the project component.

Consideration of the changes in both energy savings and other O&M expenditures forthcoming from the impervious-lined delivery canals capital renovation results in anticipated net decreases in annual costs (**Table A3**); i.e., negative values on the last row in **Table A4** represent net savings as opposed to positive values signifying increases in costs. Comparing the initial construction costs to those decreases in operating costs provides for a ratio measure of -2.17 of construction costs per dollar reduction in nominal operating expenditures, suggesting that construction costs more than double the expected nominal decreases in O&M costs during the planning period for the impervious-lined delivery canals. On a real basis, this ratio measure is -4.31 (**Table A4**), signifying construction costs are substantially higher than the expected real values of economic savings in O&M during the planning period.

Component #3 -- 24" Pipelines Replacing Delivery Canals

The '24" Pipelines Replacing Delivery Canals' component of the District's NADBank project consists of installing 5.66 miles of 24" pipelines in place of what are now concrete-lined delivery canals. Details on the cost estimates and related projections of associated water and energy savings are presented in the main body of this report (**Tables 7** and **29**). A summary of the calculated values is presented in the next section, followed by a discussion of the results corresponding to the legislated criteria. Discounted, real transformations of those nominal values are also indicated.

Summary Values

Table A5 is a summary of the key calculated values used in determining the legislated criteria results appearing in **Table A6** for the '24" Pipelines Replacing Delivery Canals' component of the District's NADBank project. These summary values are derived in RGIDECON©, using the several input parameters described in the main body of this report.

The 'Initial Construction Costs' are $1,106,080, with no difference between the nominal and real values (**Table A5**). These costs are those associated with the 24" pipelines' purchase and installation, and other implementation requirements. It is assumed all such costs occur on the first day of the planning period, thereby negating the need for any discounting of future costs and causing the nominal and real measures to be the same.

A total of 119,460 ac-ft of nominal off- and on-farm water savings are projected to occur during the 49-year productive life of the 24" pipelines. Using a 4% discount rate, the present or real value of such anticipated savings is 50,029 ac-ft (**Table A5**).

A total of 22,900,676,219 BTUs (6,711,804 kwh) of nominal energy savings is presumed associated with the forecast off- and on-farm water savings during the 49-year productive life of the 24" pipelines. Using a 4% discount rate, the present or real value of such anticipated savings is 9,590,544,355 BTUs (2,810,828 kwh) (**Table A5**).

The accrued annual net changes in O&M expenditures over the 49-year productive life of the 24" pipelines are a total decrease of $1,869,316. Using the 2002 Federal discount rate of 6.125%, this anticipated net decrease in expenditures represents a real cost reduction of $455,770 (**Table A5**). As noted in the main body of the text, this anticipated net cost savings stems from substantial energy savings and no other anticipated changes in O&M expenditures.

Criteria Stated in Guidelines

The principal evaluation criteria specified in the Public Law 106-576 legislation, transformed according to Hamilton, are presented in **Table A6** for the '24" Pipelines Replacing Delivery Canals' component of the District's NADBank project. These respective measures are calculated using the summary values reported in **Table A5.** Both nominal and real measures are presented.

The estimated costs of initial construction per ac-ft of water savings are $9.26 in a nominal sense and $22.11 in real terms (**Table A6**). The real estimates are higher than the nominal because of the discounting of future water savings in conjunction with all construction costs occurring at the onset of the project component.

The estimated costs of initial construction per BTU (kwh) of energy savings are $0.0000483 ($0.16) in a nominal sense and $0.0001153 ($0.39) in real terms (**Table A6**). The real estimates are higher than the nominal because of the discounting of future energy savings in conjunction with all construction costs occurring at the onset of the project component.

Consideration of the changes in both energy savings and other O&M expenditures forthcoming from the 24" pipelines capital renovation results in anticipated net decreases in annual costs (**Table A5**); i.e., negative values on the last row in **Table A6** represent net savings as opposed to positive values signifying increases in costs. Comparing the initial construction costs to those decreases in operating costs provides for a ratio measure of -0.59 of construction costs per dollar reduction in nominal operating expenditures, suggesting that construction costs are less than the expected nominal decreases in O&M costs during the planning period for the Impervious-lined delivery canals. On a real basis, this ratio measure is -2.48 (**Table A6**), however, signifying construction costs are substantially higher than the expected real values of economic savings in O&M during the planning period.

Component #4 –On-Farm Delivery-Site Meters

The 'On-Farm Delivery-Site Meters' component of the District's NADBank project consists of installing 400 meters at on-farm delivery sites throughout the District's service area. Details on the cost estimates and related projections of associated water and energy savings are presented in the main body of this report (**Tables 8** and **39**). A summary of the calculated values is presented in the next section, followed by a discussion of the results corresponding to the legislated criteria. Discounted, real transformations of those nominal values are also indicated.

<u>Summary Values</u>

Table A7 is a summary of the key calculated values used in determining the legislated criteria results appearing in **Table A8** for the 'On-Farm Delivery-Site Meters' component of the District's NADBank project. These summary values are derived in RGIDECON©, using the several input parameters described in the main body of this report.

The 'Initial Construction Costs' are $649,816, with no difference between the nominal and real values (**Table A7**). These costs are those associated with on-farm delivery-site meters' purchase and installation, and other implementation requirements. It is assumed all such costs occur on the first day of the planning period, thereby negating the need for any discounting of future costs and causing the nominal and real measures to be the same.

A total of 61,585 ac-ft of nominal on-farm water savings is projected to occur during the 10-year productive life of the on-farm delivery-site meters. Using a 4% discount rate, the present or real value of such anticipated savings is 48,030 ac-ft (**Table A7**).

A total of 8,739,428,083 BTUs (2,561,380 kwh) of energy savings is presumed associated with the forecast on-farm water savings during the 10-year productive life of the on-farm delivery-site meters. Using a 4% discount rate, the present or real value of such anticipated savings is 6,815,825,995 BTUs (1,997,604 kwh) (**Table A7**).

The accrued annual net changes in O&M expenditures over the 10-year productive life of the on-farm delivery-site meters are a total increase of $575,629. Using the 2002 Federal discount rate of 6.125%, this anticipated net increase in expenditures is $392,959 in real terms (**Table A7**).

Criteria Stated in Guidelines

The principal evaluation criteria specified in the Public Law 106-576 legislation, transformed according to Hamilton, are presented in **Table A8** for the 'On-Farm Delivery-Site Meters' component of the District's NADBank project. These respective measures are calculated using the summary values reported in **Table A7.** Both nominal and real measures are presented.

The estimated costs of initial construction per ac-ft of water savings are \$10.55 in a nominal sense and \$13.53 in real terms (**Table A8**). The real estimates are higher than the nominal because of the discounting of future water savings in conjunction with all construction costs occurring at the onset of the project component.

The estimated costs of initial construction per BTU (kwh) of energy savings are \$0.0000744 (\$0.25) in a nominal sense and \$0.0000953 (\$0.33) in real terms (**Table A8**). The real estimates are higher than the nominal because of the discounting of future energy savings in conjunction with all construction costs occurring at the onset of the project component.

Consideration of the changes in both energy savings and other O&M expenditures forthcoming from the on-farm delivery-site meters capital renovation results in anticipated net increases in annual costs (**Table A7**). Comparing the initial construction costs to those increases in operating costs provides for a ratio measure of 1.13 construction costs per dollar of nominal operating expenditures, suggesting that construction costs slightly exceed the expected nominal increases in O&M costs during the planning period for the on-farm delivery-site meters. On a real basis, this ratio measure is 1.65 (**Table A8**), however, signifying construction costs are substantially higher than the expected real values of economic increases in O&M during the planning period.

Summary of Legislated Criteria Results for the Individual Components

Notably, the legislated criteria results differ for the four components comprising the District's proposed NADBank project. The numbers are dissimilar to the results presented in the main body of this report due to the difference in mathematical approaches, i.e., construction costs and O&M expenditures are not comprehensively evaluated per ac-ft of water savings and per BTU (kwh) of energy savings here.

In the main body of this report, the comprehensive assessment indicates that the 24" pipelines are the most economical source of water savings, followed by on-farm delivery-site meters, impervious-lining of delivery canals, and canal meters and telemetry equipment (**Table 49**). The comprehensive costs of energy savings yielded similar rankings, but the results for the impervious-lining of delivery canals and on-farm delivery-site meters were essentially the same (**Table 50**).

Here, in the legislated criteria results, on-farm delivery-site meters are the most economical in terms of dollars of initial construction costs per ac-ft of water savings, followed by the 24" pipelines, canal meters and telemetry equipment, and the impervious-lining of delivery canals, in that ascending order of costs per ac-ft (**Tables A2**, **A4**, **A6**, and **A8**). With respect to cost of energy savings, the on-farm delivery-site meters are again the most economical, with the 24" pipelines again being the second-most economical, but the rank order of the remaining two components is opposite that noted for construction costs per ac-ft of water savings (**Tables A2**, **A4**, **A6**, and **A8**). Finally, for the construction costs per dollar of economic savings in annual O&M criterion, the occurrence of net savings in O&M for the 24" pipelines and for the impervious-lining projects appear to favor those investments (**Tables A2**, **A4**, **A6**, and **A8**). Between these two components, the 24" pipelines require less initial construction cost per dollar of economic O&M savings, apparently indicating it is the most economical. Of the remaining two alternatives, both experience an expected increase in O&M expenditures. It is difficult to determine the rank order of these two components since either a low construction cost requirement and/or a high increase in O&M expenditures result in a low ratio of the two designated calculated values. Similarly, a high construction cost requirement and/or a low increase in O&M expenditures result in a high ratio of the two designated calculated values. The resulting paradox is apparent.

Recall, however, that according to the legislated guidelines, a project proposed by a District is to be evaluated in its entirety as proposed rather than on the merits of each individual component. Appendix B contains a commentary addressing the likely aggregate performance of the total project proposed by the District, using the legislated criteria modified to account, somewhat but not completely, for the differences in useful lives of the respective project components.

Appendix B: Legislated Criteria Results Aggregated Across Components

As noted in Rister et al. (2002), aggregation of evaluation results for independent projects into an appraisal of one comprehensive project is not a common occurrence. Adaptations in analytical methods are necessary to account for the variations in useful lives of the individual components. The approach used in aggregating the legislated criteria results presented in Appendix A into one set of uniform measures utilizes the present value methods followed in the calculation of the economic and financial results reported in the main body of the text, but does not include the development of annuity equivalent measures. These compromises in approaches are intended to maintain the spirit of the legislated criteria's intentions. Here in Appendix B, only real, present value measures are presented and discussed, thereby designating all values in terms of 2002 equivalents. **Differences in useful lives across project components are not fully represented, however, in these calculated values.**

Table B1 contains the summary measures for the four respective individual components (i.e., canal meters and telemetry equipment, impervious-lining of delivery canals, 24" pipelines replacing delivery canals, and on-farm delivery-site meters) and also a summed aggregate value representing the total project for each respective measure. The project as a whole requires an initial capital construction investment of \$3,209,999. In total, 138,019 ac-ft of real water savings are estimated. Real energy savings are anticipated to be 22,990,415,520 BTUs (6,738,105 kwh). The net change in real total annual O&M expenditures is an increase of \$921,729.

Derivation of the aggregate legislated criteria measures for the project as a whole entails use of the Aggregate column values presented in **Table B1** and calculations similar to those used to arrive at the measures for the independent project components. The resulting aggregate initial construction costs per ac-ft of water savings measure is \$26.87 per ac-ft of water savings (**Table B2**). Note that this amount is lower than the comprehensive economic and financial value of **\$31.37 per ac-ft** identified in **Table 49** and discussed in the main body of this report. The difference in these values is attributable both to the incorporation of both initial capital costs and changes in operating expenses in the latter value and its treatment of the differences in the useful lives of the respective components of the proposed project.

The resulting aggregate initial construction costs per BTU (kwh) of energy savings measure is \$0.0001603 per BTU (\$0.55 per kwh) (**Table B2**). These cost estimates are lower than the **\$0.0002253 per BTU (\$0.769 per kwh)** comprehensive economic and financial cost estimates identified in **Table 50** for reasons similar to those noted above with respect to the estimates of costs of water savings.

The final aggregate legislated criterion of interest is the amount of initial construction costs per dollar of total annual economic savings. The estimate for this ratio measure is -1.30, indicating that (a) the net change in annual O&M expenditures is negative, i.e., a reduction in O&M expenditures is anticipated; and (b) \$1.30 of initial construction costs are expended for each such dollar reduction in O&M expenditures, with the latter represented in total real dollars accrued across the four project components' respective planning periods.

Appendix Tables

Table A1. Summary of Calculated Values, Canal Meters and Telemetry Equipment, Harlingen Irrigation District Cameron County No. 1, NADBank Project, 2002.

	Nominal PV	Discounted NPV
Dollars of Initial Construction Costs	$ 757,538	$ 757,538
Ac-Ft of Water Saved	30,330	21,617
BTU of Energy Saved	4,304,093,170	3,067,600,987
kwh of Energy Saved	1,261,458	899,062
$ of Annual Economic Savings (costs are + values and benefits [i.e., savings] are -)	$ 1,919,548	$ 1,136,056

Table A2. Legislated Evaluation Criteria, Canal Meters and Telemetry Equipment, Harlingen Irrigation District Cameron County No. 1, NADBank Project, 2002.

	Nominal PV	Discounted NPV
Dollar of Initial Construction Costs per Ac-Ft of Water Saved	$ 24.98	$ 35.04
Dollar of Initial Construction Costs per BTU of Energy Saved	$ 0.0001760	$0.0002470
Dollar of Initial Construction Costs per kwh of Energy Saved	$ 0.601	$ 0.843
$ of Initial Construction Costs per $ of Annual Economic Savings (costs are + values and benefits [i.e., savings] are -)	0.39	0.67

Table A3. Summary of Calculated Values, Impervious-Lining of Delivery Canals, Harlingen Irrigation District Cameron County No. 1, NADBank Project, 2002.

	Nominal PV	Discounted NPV
Dollars of Initial Construction Costs	$ 696,565	$ 696,565
Ac-Ft of Water Saved	29,478	18,343
BTU of Energy Saved	5,651,015,214	3,516,444,182
kwh of Energy Saved	1,656,218	1,030,611
$ of Annual Economic Savings (costs are + values and benefits [i.e., savings] are -)	$ -320,941	$ -161,516

Table A4. Legislated Evaluation Criteria, Impervious-Lining of Delivery Canals, Harlingen Irrigation District Cameron County No. 1, NADBank Project, 2002.

	Nominal PV	Discounted NPV
Dollar of Construction Costs per Ac-Ft of Water Saved	$ 23.63	$ 37.97
Dollar of Construction Costs per BTU of Energy Saved	$ 0.0001233	$0.0001981
Dollar of Construction Costs per kwh of Energy Saved	$ 0.421	$ 0.676
$ of Initial Construction Costs per $ of Annual Economic Savings (costs are + values and benefits [i.e., savings] are -)	-2.17	-4.31

Table A5. Summary of Calculated Values, 24" Pipelines Replacing Delivery Canals, Harlingen Irrigation District Cameron County No. 1, NADBank Project, 2002.

	Nominal PV	Discounted NPV
Dollars of Initial Construction Costs	$ 1,106,080	$ 1,106,080
Ac-Ft of Water Saved	119,460	50,029
BTU of Energy Saved	22,900,676,219	9,590,544,355
kwh of Energy Saved	6,711,804	2,810,828
$ of Annual Economic Savings (costs are + values and benefits [i.e., savings] are -)	$ -1,869,316	$ -445,770

Table A6. Legislated Evaluation Criteria, 24" Pipelines Replacing Delivery Canals, Harlingen Irrigation District Cameron County No. 1, NADBank Project, 2002.

	Nominal PV	Discounted NPV
Dollar of Construction Costs per Ac-Ft of Water Saved	$ 9.26	$ 22.11
Dollar of Construction Costs per BTU of Energy Saved	$ 0.0000483	$0.0001153
Dollar of Construction Costs per kwh of Energy Saved	$ 0.165	$ 0.394
$ of Initial Construction Costs per $ of Annual Economic Savings (costs are + values and benefits [i.e., savings] are -)	-0.59	-2.48

Table A7. Summary of Calculated Values, On-Farm Delivery-Site Meters, Harlingen Irrigation District Cameron County No. 1, NADBank Project, 2002.

	Nominal PV	Discounted NPV
Dollars of Initial Construction Costs	$ 649,816	$ 649,816
Ac-Ft of Water Saved	61,585	48,030
BTU of Energy Saved	8,739,428,083	6,815,825,996
kwh of Energy Saved	2,561,380	1,997,604
$ of Annual Economic Savings (costs are + values and benefits [i.e., savings] are -)	$ 575,629	$ 392,959

Table A8. Legislated Evaluation Criteria, On-Farm Delivery-Site Meters, Harlingen Irrigation District Cameron County No. 1, NADBank Project, 2002.

	Nominal PV	Discounted NPV
Dollar of Construction Costs per Ac-Ft of Water Saved	$ 10.55	$ 13.53
Dollar of Construction Costs per BTU of Energy Saved	$ 0.0000744	$0.0000953
Dollar of Construction Costs per kwh of Energy Saved	$ 0.254	$ 0.326
$ of Initial Construction Costs per $ of Annual Economic Savings (costs are + values and benefits [i.e., savings] are -)	1.13	1.65

Table B1. Summary of Calculated Values, Aggregated Across Canal Meters and Telemetry Equipment, Impervious-Lining of Delivery Canals, Pipelines Replacing Delivery Canals, and On-Farm Delivery-Site Meters, Harlingen Irrigation District Cameron County No. 1, NADBank Project, 2002.

Economic and Conservation Measures	Project Component				Aggregate
	Canal Meters and Telemetry Equipment	Impervious-Lined Delivery Canals	24" Pipelines Replacing Delivery Canals	On-Farm Delivery-Site Meters	
Dollars of Initial Construction Costs ($)	$757,538	$ 696,565	$ 1,106,080	$ 649,816	$3,209,999
Ac-Ft of Water Saved (ac-ft)	21,617	18,343	50,029	48,030	138,019
BTU of Energy Saved (BTU)	3,067,600,987	3,516,444,182	9,590,544,355	6,815,825,996	22,990,415,520
kwh of Energy Saved (kwh)	899,062	1,030,611	2,810,828	1,997,604	6,738,105
$ of Annual Economic Savings (- represents net savings and + represents net added costs) ($)	$ 1,136,056	$ -161,516	$ -445,770	$ 392,959	$ 921,729

Table B2. Legislated Results Criteria, Real Values, Aggregated Across Canal Meters and Telemetry Equipment, Impervious-Lining of Delivery Canals, Pipelines Replacing Delivery Canals, and On-Farm Delivery-Site Meters, Harlingen Irrigation District Cameron County No. 1, NADBank Project, 2002.

	Project Component				
Economic Measure	**Canal Meters and Telemetry Equipment**	**Impervious-Lined Delivery Canals**	**24" Pipelines Replacing Delivery Canals**	**On-Farm Delivery-Site Meters**	**Aggregate**
Dollar of Initial Construction Costs per Ac-Ft of Water Saved	$ 35.04	$ 37.97	$ 22.11	$ 13.53	$ 26.87
Dollar of Initial Construction Costs per BTU of Energy Saved	$ 0.0002470	$ 0.0001981	$ 0.0001153	$ 0.0000953	$ 0.0001603
Dollar of Initial Construction Costs per kwh of Energy Saved	$ 0.843	$ 0.676	$ 0.394	$ 0.326	$ 0.547
$ of Initial Construction Costs per $ of Annual Economic Savings (- represents net savings and + represents net added costs)	0.67	-4.31[a]	-2.48[a]	1.65	-1.30

[a] Negative values are indicative of expected net reductions in O&M expenditures during the planning horizon relative to current practices and capital installations.

— Notes —